



(11) **EP 4 443 411 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
09.10.2024 Bulletin 2024/41

(51) International Patent Classification (IPC):
G09B 29/00 (2006.01) **A01B 69/00** (2006.01)
G05D 1/02 (2020.01)

(21) Application number: **22907049.5**

(52) Cooperative Patent Classification (CPC):
A01B 69/00; G05D 1/02; G09B 29/00

(22) Date of filing: **28.10.2022**

(86) International application number:
PCT/JP2022/040394

(87) International publication number:
WO 2023/112515 (22.06.2023 Gazette 2023/25)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

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Remarks:

A request for correction of several description pages and Fig. 3A has been filed pursuant to Rule 139 EPC. A decision on the request will be taken during the proceedings before the examining division (Guidelines for Examination in the EPO, A-V, 3).

(30) Priority: **17.12.2021 JP 2021205037**

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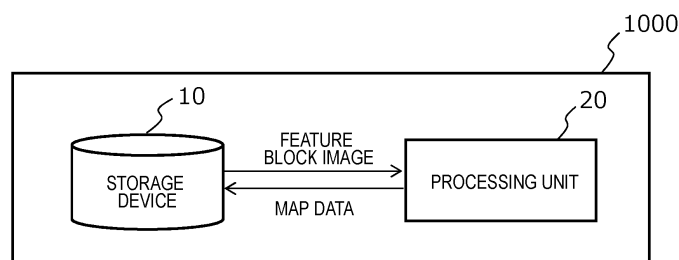
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(54) **MAP GENERATION SYSTEM AND MAP GENERATION METHOD**

(57) A map generation system generates map data for an agricultural machine to automatically travel on a road around a field. The map generation system includes a storage device to store a plurality of feature block images respectively associated with a plurality of types of features existing around the road, and a processing unit. The processing unit acquires position distribution data on one or more types of features existing around the road, the position distribution data being generated based on

at least one of sensor data from a LiDAR sensor and image data from an imager, the sensor data and the image data being output while a movable body including at least one of the LiDAR sensor and the imager is moving along the road; reads, from the storage device, one or more types of feature block images associated with the one or more types of features; and aligns the feature block images in accordance with the position distribution data to generate map data on a region including the road.

FIG. 1



Description**TECHNICAL FIELD**

[0001] The present disclosure relates to map generation systems and map generation methods.

BACKGROUND ART

[0002] Research and development has been directed to the automation of agricultural machines to be used in agricultural fields. For example, work vehicles, such as tractors, combines, and rice transplanters, which automatically travel within fields by utilizing a positioning system, e.g., a GNSS (Global Navigation Satellite System), are coming into practical use. Research and development is also under way for work vehicles which automatically travel not only within fields, but also outside the fields.

[0003] Patent Documents 1 and 2 each disclose an example of system to cause an unmanned work vehicle to automatically travel between two fields separated from each other with a road being sandwiched therebetween.

[0004] Meanwhile, development of movable bodies autonomously moving by use of a distance sensor such as a LiDAR (Light Detection and Ranging) sensor is also under way. For example, Patent Document 3 discloses an example of work vehicle automatically traveling between rows of crops by use of a LiDAR sensor.

CITATION LIST**PATENT LITERATURE**

[0005]

Patent Document 1: Japanese Laid-Open Patent Publications No. 2021-073602

Patent Document 2: Japanese Laid-Open Patent Publications No. 2021-029218

Patent Document 3: Japanese Laid-Open Patent Publications No. 2019-154379

SUMMARY OF INVENTION**TECHNICAL PROBLEM**

[0006] In order to allow an agricultural machine to automatically travel on a road outside a field (e.g., an agricultural road or a general road) in addition to inside the field, a map of an area outside the field is necessary. Such a map may be used to generate a path for self-traveling of the agricultural machine or to display the position of the agricultural machine during the self-traveling.

[0007] The present disclosure provides systems and methods to efficiently generate map data for agricultural machines performing self-traveling in environments including fields and roads around the fields.

SOLUTION TO PROBLEM

[0008] A map generation system according to an embodiment of the present disclosure generates map data for an agricultural machine automatically traveling on a road around a field. The map generation system includes a storage device to store a plurality of feature block images respectively associated with a plurality of types of features existing around the road; and a processing unit. The processing unit acquires position distribution data on one or more types of features existing around the road. The position distribution data on the features is generated based on at least one of sensor data from a LiDAR sensor and image data from an imager, the sensor data and the image data being output while a movable body including at least one of the LiDAR sensor and the imager is moving along the road. The processing unit reads, from the storage device, one or more types of feature block images associated with the one or more types of features, and aligns the feature block images in accordance with the position distribution data to generate map data on a region including the road.

[0009] General or specific aspects of the present disclosure may be implemented using a device, a system, a method, an integrated circuit, a computer program, a non-transitory computer-readable storage medium, or any combination thereof. The computer-readable storage medium may be inclusive of a volatile storage medium or a non-volatile storage medium. The device may include a plurality of devices. In the case where the device includes two or more devices, the two or more devices may be disposed within a single apparatus, or divided over two or more separate apparatuses.

ADVANTAGEOUS EFFECTS OF INVENTION

[0010] According to embodiments of the present disclosure, it is possible to efficiently generate map data for agricultural machines performing self-traveling in environments including fields and roads around the fields.

BRIEF DESCRIPTION OF DRAWINGS

[0011]

[FIG. 1] FIG. 1 is a block diagram showing an example configuration of a map generation system.

[FIG. 2A] FIG. 2A is a diagram showing examples of feature block images.

[FIG. 2B] FIG. 2B is a diagram showing an example of screen to set the size of one feature block image.

[FIG. 3A] FIG. 3A is a flowchart showing a basic operation of a processing unit.

[FIG. 3B] FIG. 3B is a diagram showing an example of relationship between position distribution data on features and map data.

[FIG. 4] FIG. 4 is a diagram showing an example of a portion of a map generated by the processing unit.

[FIG. 5] FIG. 5 shows another example configuration of the map generation system.

[FIG. 6] FIG. 6 schematically shows a movable body performing sensing while traveling on an agricultural road around a field.

[FIG. 7] FIG. 7 is a flowchart showing an example of process of generating the position distribution data on the features.

[FIG. 8] FIG. 8 is a diagram providing an overview of an agriculture management system according to an illustrative embodiment of the present disclosure.

[FIG. 9] FIG. 9 is a side view schematically showing an example of work vehicle and an example of implement that is linked to the work vehicle.

[FIG. 10] FIG. 10 is a block diagram showing an example configuration of the work vehicle and the implement.

[FIG. 11] FIG. 11 is a conceptual diagram showing an example of the work vehicle performing positioning based on an RTK-GNSS.

[FIG. 12] FIG. 12 is a diagram showing an example of operational terminal and an example of operation switches disposed in a cabin.

[FIG. 13] FIG. 13 is a block diagram showing an example of hardware configuration of a management device and a terminal device.

[FIG. 14] FIG. 14 is a diagram schematically showing an example of the work vehicle automatically traveling along a target path inside a field.

[FIG. 15] FIG. 15 is a flowchart showing an example operation of steering control during self-driving.

[FIG. 16A] FIG. 16A is a diagram showing an example of the work vehicle traveling along a target path **P**.

[FIG. 16B] FIG. 16B is a diagram showing an example of the work vehicle at a position which is shifted rightward from the target path **P**.

[FIG. 16C] FIG. 16C is a diagram showing an example of the work vehicle at a position which is shifted leftward from the target path **P**.

[FIG. 16D] FIG. 16D is a diagram showing an example of the work vehicle oriented in an inclined direction with respect to the target path **P**.

[FIG. 17] FIG. 17 is a diagram schematically showing an example of state where a plurality of the work vehicles perform self-traveling inside a field and on a road outside the field.

[FIG. 18] FIG. 18 is a table showing an example of schedule of agricultural work created by the management device.

[FIG. 19] FIG. 19 is a diagram showing an example of map that is referred to at the time of path planning.

[FIG. 20] FIG. 20 is a diagram showing an example of global path.

[FIG. 21] FIG. 21 is a diagram showing an example of global path and an example of local path generated in an environment where there is an obstacle.

DESCRIPTION OF EMBODIMENTS

(Definition of terms)

5 **[0012]** In the present disclosure, an "agricultural machine" refers to a machine for agricultural applications. Examples of agricultural machines include tractors, har-
vesters, rice transplanters, vehicles for crop manage-
ment, vegetable transplanters, mowers, seeders,
10 spreaders, and mobile robots for agriculture. Not only may a work vehicle such as a tractor function as an "ag-
ricultural machine" alone by itself, but also a combination of a work vehicle and an implement that is attached to,
or towed by, the work vehicle may function as an "agri-
cultural machine". For the ground surface inside a field,
15 the agricultural machine performs agricultural work such as tilling, seeding, preventive pest control, manure
spreading, planting of crops, or harvesting. Such agricul-
tural work or tasks may be referred to as "groundwork",
20 or simply as "work" or "tasks". Travel of a vehicle-type
agricultural machine performed while the agricultural ma-
chine also performs agricultural work may be referred to as "tasked travel".

25 **[0013]** "Self-driving" refers to controlling the movement of an agricultural machine by the action of a controller, rather than through manual operations of a driver. An
agricultural machine that performs self-driving may be referred to as a "self-driving agricultural machine" or a
"robotic agricultural machine". During self-driving, not on-
30 ly the movement of the agricultural machine, but also the operation of agricultural work (e.g., the operation of the
implement) may be controlled automatically. In the case where the agricultural machine is a vehicle- type ma-
chine, travel of the agricultural machine via self-driving
35 will be referred to as "self - traveling". The controller may control at least one of: steering that is required in the
movement of the agricultural machine, adjustment of the moving speed, or beginning and ending of a move. In the
case of controlling a work vehicle having an implement
40 attached thereto, the controller may be configured or pro-
grammed to control raising or lowering of the implement,
beginning and ending of an operation of the implement,
and so on. A move based on self-driving may include not
45 only moving of an agricultural machine that goes along a
predetermined path toward a destination, but also mov-
ing of an agricultural machine that follows a target of
tracking. An agricultural machine that performs self -driv-
ing may also move partly based on the user's instructions.
50 Moreover, an agricultural machine that performs self-
driving may operate not only in a self-driving mode but
also in a manual driving mode, where the agricultural
machine moves through manual operations of the driver.
When performed not manually but through the action of
a controller, the steering of an agricultural machine will
55 be referred to as "automatic steering". A portion of, or
the entirety of, the controller may reside outside the ag-
ricultural machine. Control signals, commands, data, etc.
may be communicated between the agricultural machine

and a controller residing outside the agricultural machine. An agricultural machine that performs self-driving may move autonomously while sensing the surrounding environment, without any person being involved in the controlling of the movement of the agricultural machine. An agricultural machine that is capable of autonomous movement is able to travel inside the field or outside the field (e.g., on roads) in an unmanned manner. During an autonomous move, operations of detecting and avoiding obstacles may be performed.

[0014] A "work plan" is data defining a plan of one or more tasks of agricultural work to be performed by an agricultural machine. The work plan may include, for example, information representing the order of the tasks of agricultural work to be performed by an agricultural machine or the field where each of the tasks of agricultural work is to be performed. The work plan may include information representing the time and the date when each of the tasks of agricultural work is to be performed. In particular, the work plan including information representing the time and the date when each of the tasks of agricultural work is to be performed is referred to as a "work schedule" or simply as a "schedule". The work schedule may include information representing the time when each task of agricultural work is to be begun and/or ended on each of working days. The work plan or the work schedule may include information representing, for each task of agricultural work, the contents of the task, the implement to be used, and/or the types and amounts of agricultural supplies to be used. As used herein, the term "agricultural supplies" refers to goods used for agricultural work to be performed by an agricultural machine. The agricultural supplies may also be referred to simply as "supplies". The agricultural supplies may include goods consumed by agricultural work such as, for example, agricultural chemicals, fertilizers, seeds, or seedlings. The work plan may be created by a processing unit communicating with the agricultural machine to manage the agricultural machine or a processing unit mounted on the agricultural machine. The processing unit can create a work plan based on, for example, information input by the user (agricultural business executive, agricultural worker, etc.) manipulating a terminal device. In this specification, the processing unit communicating with the agricultural machine to manage the agricultural machine will be referred to as a "management device". The management device may manage agricultural work of a plurality agricultural machines. In this case, the management device may create a work plan including information on each task of agricultural work to be performed by each of the plurality of agricultural machines. The work plan may be downloaded to each of the agricultural machines and stored in a storage device in each of the agricultural machines. In order to perform the scheduled agricultural work in accordance with the work plan, each agricultural machine can automatically move to a field and perform the agricultural work.

[0015] An "environment map" is data representing,

with a predetermined coordinate system, the position or the region of an object existing in the environment where the agricultural machine moves. The environment map may be referred to simply as a "map" or "map data". The coordinate system defining the environment map is, for example, a world coordinate system such as a geographic coordinate system fixed to the globe. Regarding the object existing in the environment, the environment map may include information other than the position (e.g., attribute information or other types of information). The "environment map" encompasses various type of maps such as a point cloud map and a lattice map. Data on a local map or a partial map that is generated or processed in a process of constructing the environment map is also referred to as a "map" or "map data".

[0016] A "feature" refers to an object existing on the earth. Examples of features include grass, trees, roads, fields, waterways, ditches, rivers, bridges, forests, mountains, rocks, buildings, railroad tracks, and the like. Borders, names of places, names of buildings, names of fields, names of railroad lines and the like, which do not exist in the real world, are not encompassed in the "feature" according to the present disclosure.

[0017] A "feature block image" refers to an image of a predetermined size that represents a feature, or data of the image data. The feature block image may be an image representing a feature in a simple manner. The feature block image may be, for example, a bitmap image (i.e., raster image) of a low resolution such as a pixel art image, or may be a vector image of a relatively small size. The feature block image may be a color image or a monochrome image. The feature block image is not limited to two-dimensional data, and may be three-dimensional data including information on height. One or more types of feature block images can be aligned to generate a simple environment map representing an environment around a road on which an agricultural machine is to travel. The environment map generated by aligning such feature block images is not limited to two-dimensional data, and may be three-dimensional data including information on height.

[0018] A "global path" is data on a path connecting a departure point to a target point of an automatic movement of the agricultural machine, and is generated by a processing unit performing path planning. Generation of such a global path is referred to as "global path planning". In the following description, the global path will be referred to also as a "target path" or simply as a "path". The global path may be defined by, for example, coordinate values of a plurality of points which the agricultural machine is to pass. Such a point that the agricultural machine is to pass is referred as a "waypoint", and a line segment connecting waypoints adjacent to each other is referred to as a "link".

[0019] A "local path" is a path by which the agricultural machine can avoid an obstacle, and is consecutively generated while the agricultural machine is automatically moving along the global path. Generation of such a local

path is referred to as "local path planning". The local path is consecutively generated based on data acquired by one or more sensing devices included in the agricultural machine, during a movement of the agricultural machine. The local path may be defined by a plurality of waypoints along a portion of the global path. Note that in the case where there is an obstacle in the vicinity of the global path, the waypoints may be set so as to detour around the obstacle. The length of a link between the waypoints on the local path is shorter than the length of a link between the waypoints on the global path. The device generating the local path may be the same as, or different from, the device generating the global path. For example, the management device managing the agricultural work to be performed by the agricultural machine may generate the global path, whereas the controller mounted on the agricultural machine may generate the local path. In this case, a combination of the management device and the controller functions as a "processing unit" performing the path planning. The controller of the agricultural machine may function as a processing unit performing both of global path planning and local path planning.

[0020] An "agricultural road" is a road used mainly for agriculture. An "agricultural road" is not limited to a road paved with asphalt, and encompasses unpaved roads covered with soil, gravel or the like. An "agricultural road" encompasses roads (including private roads) on which only vehicle-type agricultural machines (e.g., work vehicles such as tractors, etc.) are allowed to travel and roads on which general vehicles (automobiles, trucks, buses, etc.) are also allowed to travel. The work vehicles may automatically travel on a general road in addition to an agricultural road. The "general road" is a road maintained for traffic of general vehicles.

(Embodiments)

[0021] Hereinafter, embodiments of the present disclosure will be described. Note, however, that unnecessarily detailed descriptions may be omitted. For example, detailed descriptions on what is well known in the art or redundant descriptions on what is substantially the same configuration may be omitted. This is to avoid lengthy description, and facilitate the understanding of those skilled in the art. The accompanying drawings and the following description, which are provided by the present inventors so that those skilled in the art can sufficiently understand the present disclosure, are not intended to limit the scope of the claims. In the following description, elements having identical or similar functions are denoted by identical reference numerals.

[0022] The following embodiments are only exemplary, and the techniques according to the present disclosure are not limited to the following embodiments. For example, numerical values, shapes, materials, steps, orders of steps, layout of a display screen, etc., which are indicated in the following embodiments are only exem-

plary, and admit of various modifications so long as it makes technological sense. Any one implementation may be combined with another so long as it makes technological sense to do so.

<Embodiment of map generation system>

[0023] An example configuration of a map generation system according to an illustrative embodiment of the present disclosure will be described.

[0024] FIG. 1 is a block diagram showing an example configuration of a map generation system **1000**. The map generation system **1000** generates map data for an agricultural machine (e.g., a work vehicle such as a tractor) automatically traveling in a field and also on a road around the field. The map generation system **1000** includes a storage device **10** and a processing unit **20**.

[0025] The storage device **10** includes at least one storage medium such as, for example, a semiconductor storage medium, a magnetic storage medium or an optical storage medium. The storage device **10** stores one or more types of feature block images associated with one or more types of features that may exist around a road on which the agricultural machine is to travel (e.g., an agricultural road or a general road). The feature block image may be an image representing a feature that may exist around the road (e.g., grass, tree, ditch, waterway, bridge, field, building, mountain, forest, etc.) in a simple manner. The storage device **10** may further store a feature block image associated with the road (hereinafter, referred to also as a "road block image"). Such a feature block image may be, for example, a bitmap image of a relatively low resolution such as a pixel art image. The feature block image is not limited to a bitmap image, and may be an image of a different format such as a vector image.

[0026] FIG. 2A shows examples of feature block images. In this example, the storage device **10** stores a plurality of pixel art images respectively representing a plurality of types of features, as a plurality of feature block images. FIG. 2A shows, as examples, eight types of feature block images of the field, grass, road, tree, waterway, ditch, house and building. The feature block images shown in FIG. 2A are each a pixel art image having a relatively small size (e.g., about 32 pixels x about 32 pixels to about 256 pixels x about 256 pixels). Such feature block images may be previously created and stored in the storage device **10**. The processing unit **20** can align these feature block images to generate a map of an environment where an agricultural machine is to perform self-traveling. The feature block images are not limited to the eight types of images shown here, and may be seven or less types of images or nine or more types of images. Only one type of feature block images may be provided. For example, only the feature block images representing the road, or only one type of feature block images representing a feature other than the road, may be stored in the storage device **10**. Even in this case, the

processing unit **20** can generate a simple map allowing the road, on which the agricultural machine is to travel, to be distinguished from features other than the road.

[0027] Each feature block image may have a size (e.g., a width and a height) that is previously set to a fixed value or is manually set by a manager of the system or a user of the agricultural machine. For example, the manager or the user may be allowed to set the size of one feature block image by use of a terminal device communicable with the processing unit **20**.

[0028] FIG. **2B** shows an example of screen to set the size of one feature block image. The setting screen shown in FIG. **2B** is an example of graphical user interface (GUI) to set the width **W** (i.e., a length in a transverse direction) and the height **H** (i.e., a length in a longitudinal direction) of each of the plurality of feature block images. As in this example, the processing unit **20** can display the GUI to set the width and the height of each feature block image, on a display screen of the terminal device.

[0029] With the setting screen as shown in FIG. **2B**, it can be set how much length (e. g., in meters) in the real world corresponds to the width **W** and the height **H** of each of the plurality of feature block images (including the road block image). The manager or the user can manipulate the terminal device to set the width **W** and the height **H** of each of the plurality of feature block images of the field, grass, road, tree, waterway, ditch, house, building and the like. When the width **W** and the height **H** of each of the plurality of feature block images are set, each feature block image is stored in the storage device **10** as being associated with the width **W** and the height **H** thus set. The processing unit **20** aligns one or more types of feature block images each having the width **W** and the height **H** set on the GUI to generate map data.

[0030] In the example shown in FIG. **2B**, the aspect ratio of each feature block image may be automatically changed in accordance with the settings of the width **W** and the height **H**. The aspect ratio is expressed by, for example, the value of "width **W** : height **H**". In the case where the width **W** and the height **H** of a feature block image are of the same value, the aspect ratio of the feature block image is set to "1:1". By contrast, in the case where the width **W** is 1.0 m and the height **H** is 2.0 m, the aspect ratio of the feature block image is set to "1:2". The aspect ratio of the feature block image may be set by the terminal device displaying the setting screen or by the processing unit **20**.

[0031] In the example shown in FIG. **2B**, one feature block image is prepared for each type of feature, and the width **W** and the height **H** are set for each feature block image. Alternatively, for example, a plurality of feature block images may be prepared for each type of feature, and the width **W** and the height **H** may be allowed to set for each of the feature block images.

[0032] In the present embodiment, a function of setting the size of one feature block image in accordance with the type of feature is provided. With this function, a map reflecting the actual positional arrangement of the fea-

tures more accurately can be generated.

[0033] Instead of the function of setting the size of each feature block image being provided, the width **W** and the height **H** of each feature block image may be fixed to a length suitable to the corresponding type of feature. Even in this case, a preferred map can be generated by a map generation process described below.

[0034] The processing unit **20** may be a computer including at least one processor and at least one memory. The processing unit **20** performs an operation of generating a map by the processor executing a computer program stored in the memory. The processing unit **20** may be an assembly of a plurality of computers. For example, the processing unit **20** may include a plurality of computers communicably connected with each other via a network such as the Internet.

[0035] FIG. **3A** is a flowchart showing a basic operation of the processing unit **20**. The processing unit **20** can perform the operation from steps **S11** to **S13** shown in FIG. **3A** to generate map data on an environment where the agricultural machine is to travel. Hereinafter, the operation of each of the steps will be described.

(Step **S11**)

[0036] The processing unit **20** acquires position distribution data on one or more types of features existing around the road on which the agricultural machine is to travel. The position distribution data on the features may be generated based on at least one of sensor data from a LiDAR sensor and image data from an imager, the sensor data and the image data being output while a movable body including at least one of the LiDAR sensor and the imager is moving along the road. The movable body may be a work vehicle that is the same as the agricultural machine or a movable body different from the agricultural machine (e.g., a drone, that is, an unmanned aerial vehicle (UAV)). The position distribution data on the features may represent which of the features exist at which position in the environment where the agricultural machine is to travel. The position distribution data on the features may be represented by, for example, a combination of a position (e.g., a latitude and a longitude) in a global coordinate system (e.g., geographic coordinate system) fixed to the globe and an identifier representing the type of the feature at the position.

[0037] The position distribution data on the features may be generated by the processing unit **20** itself or another device. For example, another device such as a computer mounted on the movable body or a server computer on the cloud may generate the position distribution data on the features, and transmit the position distribution data to the processing unit **20**. The processing unit **20** or the another device may recognize one or more types of features existing around the road based on at least one of the sensor data and the image data, and generate position distribution data on the recognized one or more types of features. The recognized features may be at

least one type among, for example, grass, tree, ditch, waterway, field and building. The processing unit **20** or the another device can generate the position distribution data on the recognized features based on GNSS data output from a GNSS receiver included in the movable body and the sensor data. A more specific example of process of step **S11** will be described below.

(Step **S12**)

[0038] The processing unit **20** reads, from the storage device **10**, one or more feature block images associated with the one or more types of features in the position distribution data on the features acquired in step **S11**. In the case where, for example, the position distribution data on the features includes positional information on the eight types of features shown in FIG. **2A**, the processing unit **20** reads the feature block images corresponding to these features.

(Step **S13**)

[0039] The processing unit **20** aligns the feature block images read in step **S12**, in accordance with the position distribution data on the features acquired in step **S11** to generate map data on a region including the road on which the agricultural machine is to travel. More specifically, the processing unit **20** aligns one or more feature block images associated with the recognized one or more features, in the region in which the features exist on the map data, in accordance with the position distribution data on the features, and thus generates the map data. For example, the processing unit **20** can generate the map data by executing a process including steps **S1** to **S5** described below on each of the one or more types of features.

[0040] (**S1**) Determine the length in the transverse direction and the length in the longitudinal direction of a series of regions occupied by the feature, in accordance with the position distribution data. Herein, the transverse direction corresponds to the direction of the width of the feature block image, and the longitudinal direction corresponds to the direction of the height of the feature block image.

[0041] (**S2**) Divide the length in the transverse direction by the width of the feature block image corresponding to the feature, and thus determine a transverse number of feature block images.

[0042] (**S3**) Divide the length in the longitudinal direction by the height of the feature block image corresponding to the feature, and thus determine a longitudinal number of feature block images.

[0043] (**S4**) Align the feature block images by the transverse number in the transverse direction.

[0044] (**S5**) Align the feature block images by the longitudinal number in the longitudinal direction.

[0045] The steps (**S1**) to (**S5**) may be preferably applied in the case where the feature has a planar shape

that can be approximated by a rectangle. In the case where the planar shape of the feature cannot be approximated by a rectangle, the region occupied by the feature is divided into a plurality of rectangular or strip-shaped regions having different sizes, and the process including steps (**S1**) to (**S5**) is applied to each of the regions. Thus, the map data can be generated.

[0046] Hereinafter, an example of process of aligning the feature block images will be described in detail with reference to FIG. **3B**.

[0047] FIG. **3B** shows an example of relationship between position distribution data on features and map data generated by aligning one or more types of feature block images. Part (**a**) in the upper half of FIG. **3B** shows an example of positional arrangement of the features represented by the position distribution data. Part (**b**) in the lower half of FIG. **3B** shows an example of generated map. The following description will be made by use of an xy coordinate system shown in FIG. **3B**. An x axis and a y axis cross each other perpendicularly. A direction of the x axis will be referred to as a "transverse direction", and a direction of the y axis will be referred to as a "longitudinal direction". The transverse direction corresponds to the width direction of the feature block images, and the longitudinal direction corresponds to the height direction of the feature block images. In this example, the position distribution data on the features includes positional arrangement information on the grass, the road and the house. For easier understanding, it is assumed that a series of regions occupied by each of the grass, the road and the house has a rectangular planar shape having two sides parallel to the x axis and two sides parallel to the y axis.

[0048] In the example shown in FIG. **3B**, the processing unit **20** sets an arbitrary point in the position distribution data as a reference point, and acquires positional information on each of the features such as the grass, the road, the house and the like represented by the position distribution data, along the transverse direction and along the longitudinal direction from the reference point. Thus, the processing unit **20** specifies the series of regions occupied by each feature. For example, regarding the grass on the left side of FIG. **3B**, a region having a length **L1** in the transverse direction from reference point **Pa** and a length **L2** in the longitudinal direction from reference point **Pa** is specified as a region occupied by the grass on the left side. The processing unit **20** divides the length **L1**, in the transverse direction, of the grass on the left side by the width **W** of the feature block image representing the grass to find the number of feature block images to be aligned in the transverse direction (hereinafter, such an number will be referred to as a "transverse number"). The processing unit **20** divides the length **L2**, in the longitudinal direction, of the grass on the left side by the height **H** of the feature block image representing the grass to find the number of feature block images to be aligned in the longitudinal direction (hereinafter, such an number will be referred to as a "longitudinal number").

The processing unit **20** aligns the feature block images by the transverse number in the transverse direction sequentially from reference point **Pa**, and aligns the feature block images by the longitudinal number in the longitudinal direction sequentially from reference point **Pa**. As a result, as shown in the lower half of FIG. **3B**, region **A1** of the grass on the left side in the map can be generated.

[0049] There is a case where division of the length **L1** in the transverse direction with the width **W** of the feature block image or division of the length **L2** in the longitudinal direction with the height **H** of the feature block image does not result in an integer. In this case, the processing unit **20** may enlarge or contract a portion of the feature block images to be aligned in at least one of the transverse direction and the longitudinal direction, and thus generate map data corresponding to the position distribution data on the features.

[0050] Regarding the grass on the right side, the processing unit **20** determines a length **L3** in the transverse direction and a length **L4** in the longitudinal direction of a region of the grass on the right side based on the position distribution data in substantially the same manner as described above. The processing unit **20** finds the transverse number by an arithmetic operation of $L3/W$, and finds the longitudinal number by an arithmetic operation of $L4/H$. The processing unit **20** aligns the feature block images by the transverse number in the transverse direction from reference point **Pb**, and aligns the feature block images by the longitudinal number in the longitudinal direction from reference point **Pb**. As a result, region **A2** of the grass on the right side in the map can be generated.

[0051] The processing unit **20** executes substantially the same process as described above regarding the road and the house. The processing unit **20** searches for features in the transverse direction and the longitudinal direction in the position distribution data on the features and as a result, detects a border between different types of features. In this case, the processing unit **20** sets a point on the border as a new reference point. In the case where, for example, a border between the grass and the house is detected at point **Pc** in FIG. **3B**, the processing unit **20** sets point **Pc** as a new reference point. The processing unit **20** finds the transverse number and the longitudinal number of the feature block images of the house based on the lengths, in the transverse direction and the longitudinal direction, of a region occupied by the house, and aligns the feature block images by the transverse number and the longitudinal number.

[0052] In general, the region occupied by each of the features such as the grass, the road, the house and the like has a planar shape different from a rectangle. The processing unit **20** regards the region occupied by each feature as an assembly of a plurality of rectangular or strip-shaped regions having different sizes, and applies the above-described process for each of the regions. Thus, the processing unit **20** can generate map data.

[0053] The above-described process is merely an ex-

ample, and the map data may be generated by another method. For example, the processing unit **20** may detect the width of a road around the field based on at least one of the sensor data and the image data, align the road block images in the width direction by the number corresponding to the width of the road, and thus generate map data reflecting the width of the road. In this case, features other than the road may be represented by one type of feature block images. After aligning the feature block images, the processing unit **20** may execute a process of smoothing the border between different types of feature block images or a process of interpolating an area of an unknown type of feature with an image of the feature existing around such an area, and thus generate map data as a final product.

[0054] FIG. **4** shows an example of a portion of the map generated in step **S13**. The map in this example is of the bitmap format created by aligning nine types of feature block images (pixel art images in this example) shown at the bottom of FIG. **4**. The processing unit **20** can generate the map shown in FIG. **4** by a process of disposing each feature block image at a position corresponding thereto as represented by the position distribution data on the features. In this manner, the processing unit **20** can align the plurality of types of feature block images recorded in the storage device **10** to generate the map data.

[0055] The processing unit **20** may dispose the feature block image of each feature as being enlarged or contracted to an appropriate size. For example, the feature block images representing structural bodies such as a house and a building may be disposed in a state of being relatively large, whereas the feature block images representing grass, an agricultural road, a waterway and a ditch may be disposed in a state of being relatively small. Such a process can smooth the border between the feature block images aligned and allow a map reflecting an actual state of the region better to be generated.

[0056] In the example shown in FIG. **4**, a road block image associated with roads is used, and the generated map reflects the actual position and the actual width of each of the roads. As can be seen, the processing unit **20** may align one or more types of feature block images associated with one or more types of features and also the road block image associated with the roads, in accordance with the position distribution data on the features to generate the map data. Even in the case where the road block image is not used, the processing unit **20** may align the feature block images of the grass and the like existing on both of two sides of each road, and thus generate map data representing a region between these feature block images as a road.

[0057] The map shown in FIG. **4** represents the environment where the agricultural machine is to travel in a simple manner, but represents the position and the width of each of the roads around the fields correctly. Generation of such a map allows path planning for self-traveling of the agricultural machine to be performed appropriately.

[0058] Unlike general self-driving vehicles, agricultural machines performing self-driving often travel at a low speed, and travel on agricultural roads around fields more often than on general roads where pedestrians and automobiles come and go frequently. Such self-driving agricultural machines are required to travel on the agricultural roads appropriately and to go back and forth between the agricultural roads and the fields automatically and smoothly. This requires a map representing the positions and the widths of the agricultural roads around the fields correctly. However, such a map is not generally available. Maps for general self-driving vehicles are widely available, but many of such maps are not applicable to the self-driving agricultural machines. The maps for the general self-driving vehicles include detailed information on roads such as general roads and freeways but often lack in information on fields and agricultural roads. For example, in general, such maps do not include information on entrances/exits of the fields or do not correctly show the shapes of the fields or the widths of the agricultural roads adjacent to the fields. The maps for the general self-driving vehicles include much information that is not necessary for the agricultural machines (e.g., information on the roads on which the agricultural machines would not travel, such as freeways). Therefore, maps for the general vehicles are not always suitable to create or display a path for the self-driving agricultural machines.

[0059] The map generation system **1000** according to the present embodiment can generate, by a simple process, a map correctly representing the position and the width of each of the roads around the fields and representing features other than the roads in a simple manner. Therefore, it can efficiently generate a map suitable to create or display a path along which an agricultural machine is to travel.

[0060] Now, a specific example of configuration and operation of the map generation system **1000** according to the present embodiment will be described.

[0061] FIG. 5 is a block diagram showing another example configuration of the map generation system **1000**. The map generation system **1000** in this example further includes a movable body **30** in addition to the storage device **10** and the processing unit **20**. The processing unit **20** in this example is configured to execute processes of recognizing the features, generating position distribution data on the features, aligning feature block images, and generating map data, based on data acquired from the movable body **30**. Each of these processes may be implemented as a software module or a hardware module (e.g., a circuit).

[0062] The movable body **30** includes a LiDAR sensor **33**, a camera **34**, and a GNSS unit **35**. While moving, the movable body **30** collects data required by the processing unit **20** to generate map data, by use of the LiDAR sensor **33**, the camera **34** and the GNSS unit **35**. The data collected by the LiDAR sensor **33**, the camera **34** and the GNSS unit **35** is provided to the processing unit **20** via a

wired or wireless network or a storage medium. The movable body **30** may be the same as, or different from, the agricultural machine using the map data generated by the processing unit **20**. The movable body **30** is not limited to an agricultural machine such as a work vehicle, and may be an aerial vehicle such as a drone.

[0063] The LiDAR sensor **33** uses light to measure the distance to an object around the movable body **30**. The LiDAR sensor **33** generates and outputs sensor data representing the distance distribution or the position distribution of objects existing around the movable body **30**. The LiDAR sensor **33** may be, for example, a scanner-type sensor that acquires information on the distance distribution or the position distribution of objects in the space by scanning performed by a laser beam. Alternatively, the LiDAR sensor **33** may be a flash-type sensor that acquires information on the distance distribution or the position distribution of objects in the space by use of light diffused in a wide range.

[0064] The LiDAR sensor **33** may be configured to, for example, emit a pulse-like laser beam (i.e., a laser pulse), measure the time period required for the laser pulse reflected by an object around the movable body **30** to return to the LiDAR sensor **33**, and calculate the distance to the point of reflection on a surface of the object based on the time period. Alternatively, the LiDAR sensor **33** may measure the distance by use of the FMCW (Frequency Modulated Continuous Wave) technology. A LiDAR sensor using the FMCW technology emits laser light having a frequency thereof modulated linearly, and can find the distance to the point of reflection and the speed based on the frequency of a beat signal acquired by detecting the interference light of the emitted light and the reflected light.

[0065] The LiDAR sensor **33** may be configured to output sensor data including information on the distance and the direction to each of points of reflection. Alternatively, the LiDAR sensor **33** may calculate coordinate values of each point of reflection in a coordinate system fixed to the movable body **30** (hereinafter, this coordinate system will be referred to as a "movable body coordinate system") based on the information on the distance and the direction to each point of reflection, and output sensor data including the coordinate values. The sensor data may include luminance information on each point of reflection. The luminance information on each point of reflection may be used to specify the type of the feature positioned at the point of reflection.

[0066] The LiDAR sensor **33** may be a two-dimensional LiDAR sensor or a three-dimensional LiDAR sensor. A two-dimensional LiDAR sensor may scan the environment in a state where the laser beam rotates within one plane. By contrast, a three-dimensional LiDAR sensor may scan the environment in a state where a plurality of laser beams rotate along different conical surfaces respectively. Data necessary to generate a three-dimensional map may be collected by use of the three-dimensional LiDAR sensor.

[0067] The coordinate values (two-dimensional or three-dimensional coordinate values) of each point of reflection that are calculated based on the information on the distance and the direction generated by the LiDAR sensor **33** are expressed in the movable body coordinate system. The processing unit **20** converts the coordinate values of each point of reflection in the movable body coordinate system into those in the world coordinate system fixed to the globe, and thus can acquire the coordinate values of each point of reflection in the world coordinate system. As a result, two-dimensional or three-dimensional point cloud data can be generated. In order to convert the coordinate values in the movable body coordinate system into those in the world coordinate system, information on a pose (i.e., the position and the orientation) of the movable body **30** is required. The pose of the movable body **30** may be determined based on GNSS data output from the GNSS unit **35**.

[0068] The camera **34** is an imager that images the environment around the movable body **30** to generate image data. The camera **34** may include, for example, an image sensor acquiring a visible light image or an infrared image, and a lens optical system forming an image at the image sensor. The camera **34** generates data on a moving image of a predetermined frame rate. The image data output from the camera **34** may be used to recognize objects existing in the space.

[0069] The GNSS unit **35** includes a GNSS receiver, and generates GNSS data including positional information on the movable body **30**. The GNSS receiver may include an antenna receiving signals from GNSS satellites and a processor calculating the position of a work vehicle **100** based on the signals received by the antenna. The GNSS unit **35** receives satellite signals transmitted from a plurality of GNSS satellites and performs positioning based on the satellite signals. GNSS is the general term for satellite positioning systems such as GPS (Global Positioning System), QZSS (Quasi-Zenith Satellite System; e.g., MICHIBIKI), GLONASS, Galileo, and BeiDou.

[0070] The GNSS unit **35** may include an inertial measurement unit (IMU). The IMU may include, for example, a direction sensor such as a 3-axis accelerometer, a 3-axis gyroscope or a 3-axis geomagnetic sensor. The IMU measures a tilt, a small motion and an orientation of the movable body **30**. The GNSS unit **35** complements the position data based on the satellite signals by use of the data acquired by the IMU, and thus can estimate the position and the orientation of the movable body **30** at a high accuracy. The IMU may be provided independently from the GNSS unit **35**.

[0071] FIG. 6 schematically shows the movable body **30** performing sensing by use of the LiDAR sensor **33** and the camera **34** while traveling on an agricultural road around a field. The movable body **30** in this example is a work vehicle of the same type as that of the agricultural machine using the map data (e.g., a tractor). The movable body **30** may be another type of movable body such

as, for example, a drone. In FIG. 6, the fan shape defined by the dashed line schematically shows an example of range of sensing performed by use of the LiDAR sensor **33** or the camera **34**. The movable body **30** may be moved by driving or remote operation performed by the driver (operator). Alternatively, the movable body **30** may automatically move while performing localization and map generation at the same time based on the sensor data from the LiDAR sensor **33** by use of an algorithm such as SLAM (Simultaneous Localization and Mapping).

[0072] While the movable body **30** is moving, the LiDAR sensor **33** measures the distance to each of features existing around the movable body **30**, whereas the camera **34** images the surrounding environment of the movable body **30**. The GNSS unit **35** repeatedly measures the position and the orientation of the movable body **30**. While moving, the movable body **30** accumulates the sensor data output from the LiDAR sensor **33**, the image data output from the camera **34** and the GNSS data output from the GNSS unit **35** in the storage device included in the movable body **30**, with such data being associated with, for example, information on the date and time. The sensor data, the image data and the GNSS data thus accumulated are transmitted to the processing unit **20** at a certain timing and used to generate the map data.

[0073] The processing unit **20** in this example generates the map data based on the sensor data, the image data and the GNSS data. More specifically, the processing unit **20** performs the operation shown in FIG. 3 to generate the map data. In step **S11** shown in FIG. 3, the processing unit **20** generates the position distribution data on the features based on the sensor data, the image data and the GNSS data.

[0074] FIG. 7 is a flowchart showing an example of process, executed by the processing unit **20**, of generating the position distribution data on the features. The processing unit **20** in this example executes processes of steps **S111**, **S112** and **S113** in step **S11** shown in FIG. 3. Hereinafter, the process of each step will be described.

(Step **S111**)

[0075] The processing unit **20** acquires the sensor data, the image data and the GNSS data collected by the movable body **30** during the movement of the movable body **30** on the road around the field.

(Step **S112**)

[0076] The processing unit **20** recognizes one or more types of features existing around the road based on the acquired image data. The processing unit **20** recognizes, for example, features including at least one type among grass, tree, ditch, waterway, field and building existing around the road based on the image data. The processing unit **20** can recognize one or more types of features existing around the road by executing a process of pattern matching, segmentation or the like based on the im-

age data. For recognition of the features, image recognition by machine learning may be used. For example, the processing unit **20** may recognize the features in the image by semantic segmentation using the convolutional neural network (CNN). The image recognition is not limited to using any specific algorithm, and may use any algorithm. The processing unit **20** may detect a border between the road and another feature or detect the width of the road by image recognition. The processing unit **20** may use information on the border between the road and the another feature and/or information on the width of the road for the process of aligning the feature block images in step **S13** to be executed later.

(Step **S113**)

[0077] The processing unit **20** generates position distribution data on the features recognized in step **S112**, based on the GNSS data and the sensor data. The processing unit **20**, for example, calculates the position coordinate values (e.g., the latitude and the longitude) of each of points of reflection in the geographic coordinate system, based on the distance and the direction to each point of reflection represented by the sensor data and also the distance and the orientation of the movable body **30** represented by the GNSS data. At this point, the processing unit **20** may calculate three-dimensional position coordinate values including information on the altitude of each point of reflection. As a result, the processing unit **20** can generate two-dimensional or three-dimensional point cloud data representing the objects existing in the surrounding environment of the movable body **30**. The processing unit **20** performs matching of the image data and the point cloud data to specify a range for the position of a point corresponding to each feature recognized in step **S112**. For example, the processing unit **20** may generate, as the position distribution data on the feature, data showing an identifier representing the type of each recognized feature and also showing the range for the position coordinate values of the corresponding point. In this manner, the processing unit **20** can generate position distribution data representing the distribution of the positions (e.g., the latitude and the longitude) of one or more types of features, based on the GNSS data and the sensor data.

[0078] As a result of the above-described processes, the processing unit **20** can generate the position distribution data on the features recognized based on the image data. After step **S113**, the processing unit **20** executes the processes of steps **S12** and **S13** shown in FIG. **3** to generate the map data.

[0079] In step **S13**, the processing unit **20** aligns one or more types of feature block images associated with the one or more types of features recognized in step **S112**, in the region where the features exist on the map data in accordance with the position distribution data, and thus generates the map data. The processing unit **20** aligns the feature block images such that, for example,

the width of the road recognized in step **S112** is correctly reflected. As a result, a map suitable to the path planning for the agricultural machine can be generated. The processing unit **20** may generate the map without using the road block image representing the road. For example, the processing unit **20** may generate a map by aligning one or more types of feature block images other than the road block image along, and outward of, the border between the road and a feature other than the road, and disposing an image representing the road (e.g., an image of a specific color or pattern) inward of the border.

[0080] In the above-described example, the movable body **30** includes both of the LiDAR sensor **33** and the camera **34** (i.e., the imager). The movable body **30** may include only either the LiDAR sensor **33** or the camera **34**. Even in this case, the processing unit **20** can detect and recognize the features based on the data output from the LiDAR sensor **33** or the camera **34** to generate the position distribution data on the features. For example, the processing unit **20** can generate position distribution data representing the distribution of the road and the features other than the road, based on information representing the distance to, or the position of, each of the points of reflection and also the luminance information on each point of reflection, both information being included in the sensor data output from the LiDAR sensor **33**. The light reflectance is different among the features, and therefore, the features can be distinguished from each other based on the luminance information on the point of reflection. Alternatively, an imager that can acquire distance information such as a ToF (Time of Flight) camera or a stereo camera can be used to provide the same results as in the case where the LiDAR sensor **33** is used. The movable body **30** may perform positioning or localization by another method, instead of using the GNSS unit **35**. For example, the movable body **30** may automatically move while performing localization and map generation at the same time based on the sensor data by use of an algorithm such as SLAM. In this case, the processing unit **20** may execute the process of recognizing the features and the process of aligning the feature block images described above, based on the map generated by the movable body **30** (e.g., a point cloud map), to generate map data as a final product.

[0081] After generating the map data by the above-described method, the processing unit **20** may generate a path for self-traveling of the agricultural machine along the road, based on the map data. The path may be generated by a device different from the processing unit **20** (e.g., a computer mounted on the agricultural machine or a server computer on the cloud). The agricultural machine performs self-traveling along the generated path (hereinafter, may be referred to as a "target path" or a "global path"). The processing unit **20** may display the generated map or path on a display screen of the terminal device used by the user.

<Embodiment of agricultural management system>

[0082] Now, an embodiment of a system to manage an agricultural machine performing self-driving based on the map data created by the above-described method will be described. Hereinafter, embodiments in which techniques according to the present disclosure are applied to a work vehicle, such as a tractor, which is an example of agricultural machine, will be mainly described. The techniques according to the present disclosure are also applicable to other types of agricultural machines in addition to the work vehicle such as a tractor.

[0083] FIG. 8 is a diagram providing an overview of an agriculture management system according to an illustrative embodiment of the present disclosure. The agriculture management system shown in FIG. 8 includes a work vehicle **100**, a terminal device **400**, and a management device **600**. The terminal device **400** is a computer used by a user performing remote monitoring of the work vehicle **100**. The management device **600** is a computer managed by a business operator running the agriculture management system. The work vehicle **100**, the terminal device **400** and the management device **600** can communicate with each other via the network **80**. FIG. 8 shows one work vehicle **100**, but the agriculture management system may include a plurality of the work vehicles or any other agricultural machine.

[0084] The work vehicle **100** according to the present embodiment is a tractor. The work vehicle **100** can have an implement attached to its rear and/or its front. While performing agricultural work in accordance with a particular type of implement, the work vehicle **100** is able to travel inside a field. The work vehicle **100** may travel inside the field or outside the field with no implement being attached thereto.

[0085] The work vehicle **100** has a self-driving function. In other words, the work vehicle **100** can travel by the action of a controller, rather than manually. The controller according to the present embodiment is provided inside the work vehicle **100**, and is able to control both the speed and steering of the work vehicle **100**. The work vehicle **100** can perform self-traveling outside the field (e.g., on roads) as well as inside the field.

[0086] The work vehicle **100** includes a device usable for positioning or localization, such as a GNSS receiver or an LiDAR sensor. Based on the position of the work vehicle **100** and information on a target path, the controller of the work vehicle **100** causes the work vehicle **100** to automatically travel. In addition to controlling the travel of the work vehicle **100**, the controller also controls the operation of the implement. As a result, while automatically traveling inside the field, the work vehicle **100** is able to perform agricultural work by using the implement. In addition, the work vehicle **100** is able to automatically travel along the target path on a road outside the field (e.g., an agricultural road or a general road). In the case of performing self-traveling on a road outside the field, the work vehicle **100** travels while generating, along the

target path, a local path along which the work vehicle **100** can avoid an obstacle, based on data output from a sensing device such as a camera or the LiDAR sensor. Inside the field, the work vehicle **100** may travel while generating a local path in substantially the same manner as described above, or may perform an operation of traveling along the target path without generating a local path and halting when an obstacle is detected.

[0087] The management device **600** is a computer to manage the agricultural work performed by the work vehicle **100**. The management device **600** may be, for example, a server computer that performs centralized management on information regarding the field on the cloud and supports agriculture by use of the data on the cloud. The management device **600**, for example, creates a map of an environment where the work vehicle **100** is to travel and a work plan for the work vehicle **100**, and performs global path planning for the work vehicle **100** in accordance with the map and the work plan. The management device **600** generates a map of the environment where the work vehicle **100** is to travel by substantially the same method as described above with reference to FIG. 1 to FIG. 7. That is, the management device **600** recognizes one or more types of features existing in the environment, based on the data collected by the work vehicle **100** or another movable body by use of at least one of the LiDAR sensor and an imager, and aligns feature block images corresponding to the recognized features to generate an environment map. The management device **600** generates a global path (target path) for the work vehicle **100** based on the generated environment map. In the present embodiment, the management device **600** functions as a map generation system generating map data for self-driving of the agricultural machine.

[0088] The management device **600** generates a target path inside the field and a target path outside the field by different methods from each other. The management device **600** generates a target path inside the field based on information regarding the field. For example, the management device **600** can generate a target path inside the field based on various types of previously registered information such as the outer shape of the field, the area size of the field, the position of the entrance/exit of the field, the width of the work vehicle **100**, the width of the implement, the contents of the work, the types of crops to be grown, the region where the crops are to be grown, the growing states of the crops, and the interval between rows or ridges of the crops. The management device **600** generates a target path inside the field based on, for example, information input by the user by use of the terminal device **400** or any other device. The management device **600** generates a target path inside the field such that the path covers, for example, the entirety of a work area where the work is to be performed. Meanwhile, the management device **600** generates a path outside the field in accordance with the work plan or the user's instructions. For example, the management device **600** can generate a target path outside the field based on various

types of information such as the order of tasks of agricultural work indicated by the work plan, the position of the field where each task of agricultural work is to be performed, the position of the entrance/exit of the field, the time when each task of agricultural work is to begin and/or end, the state of the road surface, the state of weather or the traffic state. The management device 600 may generate a target path based on information representing the path or the waypoints specified by the user manipulating the terminal device 400, without relying on the work plan. The management device 600 transmits data on the work plan, the target path and the environment map thus generated to the work vehicle 100. The work vehicle 100 automatically moves and performs agricultural work based on the data.

[0089] The global path planning and the generation (or editing) of the environment map may be performed by any other device than the management device 600. For example, the controller of the work vehicle 100 may perform global path planning, or the generation or editing of the environment map.

[0090] The terminal device 400 is a computer that is used by a user who is at a remote place from the work vehicle 100. The terminal device 400 shown in FIG. 8 is a laptop computer, but the terminal device 400 is not limited to this. The terminal device 400 may be a stationary computer such as a desktop PC (personal computer), or a mobile terminal such as a smartphone or a tablet computer. The terminal device 400 may be used to perform remote monitoring of the work vehicle 100 or remote-manipulate the work vehicle 100. For example, the terminal device 400 can display, on a display screen thereof, a video captured by one or more cameras (imagers) included in the work vehicle 100. The user can watch the video to check the state of the surroundings of the work vehicle 100 and instruct the work vehicle 100 to halt or begin traveling. The terminal device 400 can also display, on the display screen thereof, a setting screen allowing the user to input information necessary to create a work plan (e.g., a schedule of each task of agricultural work) for the work vehicle 100. When the user inputs necessary information to the setting screen and performs a manipulation to transmit the information, the terminal device 400 transmits the input information to the management device 600. The management device 600 creates a work plan based on the information. The terminal device 400 may also be used to register one or more fields where the work vehicle 100 is to perform the agricultural work. The terminal device 400 may further have a function of displaying, on a display screen thereof, a setting screen allowing the user to input information necessary to set a target path. The terminal device 400 may display the map generated by the management device 600 (e.g., the map shown in FIG. 4) on the setting screen. The user may perform a manipulation of setting a target path on the displayed map.

[0091] Hereinafter, a configuration and an operation of the system according to the present embodiment will be

described in more detail.

[1. Configuration]

5 [0092] FIG. 9 is a side view schematically showing an example of the work vehicle 100 and an example of implement 300 linked to the work vehicle 100. The work vehicle 100 according to the present embodiment can operate both in a manual driving mode and a self-driving mode. In the self-driving mode, the work vehicle 100 is able to perform unmanned travel. The work vehicle 100 can perform self-driving both inside a field and outside the field.

10 [0093] As shown in FIG. 9, the work vehicle 100 includes a vehicle body 101, a prime mover (engine) 102, and a transmission 103. On the vehicle body 101, wheels 104 with tires and a cabin 105 are provided. The wheels 104 include a pair of front wheels 104F and a pair of rear wheels 104R. Inside the cabin 105, a driver's seat 107, a steering device 106, an operational terminal 200, and switches for manipulation are provided. In the case where the work vehicle 100 performs tasked travel inside the field, the front wheels 104F and/or the rear wheels 104R may have crawlers, rather than tires, attached thereto.

25 [0094] The work vehicle 100 includes a plurality of sensing devices sensing the surroundings of the work vehicle 100. In the example shown in FIG. 9, the sensing devices include a plurality of cameras 120, a LiDAR sensor 140, and a plurality of obstacle sensors 130.

30 [0095] The cameras 120 may be provided at the front/rear/right/left of the work vehicle 100, for example. The cameras 120 image the surrounding environment of the work vehicle 100 and generate image data. The images acquired by the cameras 120 may be transmitted to the terminal device 400, which is responsible for remote monitoring. The images may be used to monitor the work vehicle 100 during unmanned driving. The cameras 120 may also be used to generate images to allow the work vehicle 100, traveling on a road outside the field (an agricultural road or a general road), to recognize features, obstacles, white lines, road signs, traffic signs or the like in the surroundings of the work vehicle 100.

35 [0096] The LiDAR sensor 140 in the example shown in FIG. 9 is disposed on a bottom portion of a front surface of the vehicle body 101. The LiDAR sensor 140 may be disposed at any other position. While the work vehicle 100 is traveling mainly outside the field, the LiDAR sensor 140 repeatedly outputs sensor data representing the distance and the direction between an object existing in the surrounding environment thereof and each of measurement points, or a two-dimensional or three-dimensional coordinate values of each of the measurement points. The sensor data output from the LiDAR sensor 140 is processed by the controller of the work vehicle 100. The controller can perform localization of the work vehicle 100 by matching the sensor data against the environment map. The controller can further detect an object such as an obstacle existing in the surroundings of the work ve-

hicle **100** based on the sensor data, and generate, along the global path, a local path along which the work vehicle **100** needs to actually proceed. The controller can utilize an algorithm such as, for example, SLAM to generate or edit an environment map. The work vehicle **100** may include a plurality of LiDAR sensors disposed at different positions with different orientations.

[0097] The plurality of obstacle sensors **130** shown in FIG. **9** are provided at the front and the rear of the cabin **105**. The obstacle sensors **130** may be disposed at other positions. For example, one or more obstacle sensors **130** may be disposed at any position at the sides, the front or the rear of the vehicle body **101**. The obstacle sensors **130** may include, for example, a laser scanner or an ultrasonic sonar. The obstacle sensors **130** may be used to detect obstacles in the surroundings of the work vehicle **100** during self-traveling to cause the work vehicle **100** to halt or detour around the obstacles. The LiDAR sensor **140** may be used as one of the obstacle sensors **130**.

[0098] The work vehicle **100** further includes a GNSS unit **110**. The GNSS unit **110** includes a GNSS receiver. The GNSS receiver may include an antenna to receive a signal (s) from a GNSS satellite (s) and a processor to calculate the position of the work vehicle **100** based on the signal (s) received by the antenna. The GNSS unit **110** receives satellite signals transmitted from the plurality of GNSS satellites, and performs positioning based on the satellite signals. Although the GNSS unit **110** according to the present embodiment is disposed above the cabin **105**, it may be disposed at any other position.

[0099] The GNSS unit **110** may include an inertial measurement unit (IMU). Signals from the IMU can be used to complement position data. The IMU can measure a tilt or a small motion of the work vehicle **100**. The data acquired by the IMU can be used to complement the position data based on the satellite signals, so as to improve the performance of positioning.

[0100] The controller of the work vehicle **100** may utilize, for positioning, the sensing data acquired by the sensing devices such as the cameras **120** or the LiDAR sensor **140**, in addition to the positioning results provided by the GNSS unit **110**. In the case where features serving as characteristic points exist in the environment that is traveled by the work vehicle **100**, as in the case of an agricultural road, a forest road, a general road or an orchard, the position and the orientation of the work vehicle **100** can be estimated with a high accuracy based on data that is acquired by the cameras **120** or the LiDAR sensor **140** and on an environment map that is previously stored in the storage device. By correcting or complementing position data based on the satellite signals using the data acquired by the cameras **120** or the LiDAR sensor **140**, it becomes possible to identify the position of the work vehicle **100** with a higher accuracy.

[0101] The prime mover **102** may be a diesel engine, for example. Instead of a diesel engine, an electric motor may be used. The transmission **103** can change the pro-

pulsion and the moving speed of the work vehicle **100** through a speed changing mechanism. The transmission **103** can also switch between forward travel and backward travel of the work vehicle **100**.

5 [0102] The steering device **106** includes a steering wheel, a steering shaft connected to the steering wheel, and a power steering device to assist in the steering by the steering wheel. The front wheels **104F** are the steered wheels, such that changing their angle of turn (also referred to as "steering angle") can cause a change in the traveling direction of the work vehicle **100**. The steering angle of the front wheels **104F** can be changed by manipulating the steering wheel. The power steering device includes a hydraulic device or an electric motor to supply an assisting force to change the steering angle of the front wheels **104F**. When automatic steering is performed, under the control of the controller disposed in the work vehicle **100**, the steering angle may be automatically adjusted by the power of the hydraulic device or the electric motor.

20 [0103] A linkage device **108** is provided at the rear of the vehicle body **101**. The linkage device **108** includes, e.g., a three-point linkage (also referred to as a "three-point link" or a "three-point hitch"), a PTO (Power Take Off) shaft, a universal joint, and a communication cable. The linkage device **108** allows the implement **300** to be attached to, or detached from, the work vehicle **100**. The linkage device **108** is able to raise or lower the three-point link with a hydraulic device, for example, thus changing the position and/or attitude of the implement **300**. Moreover, motive power can be sent from the work vehicle **100** to the implement **300** via the universal joint. While towing the implement **300**, the work vehicle **100** allows the implement **300** to perform a predetermined task. The linkage device may be provided frontward of the vehicle body **101**. In that case, the implement can be connected frontward of the work vehicle **100**.

35 [0104] Although the implement **300** shown in FIG. **9** is a rotary tiller, the implement **300** is not limited to a rotary tiller. For example, any arbitrary implement such as a seeder, a spreader, a transplanter, a mower, a rake implement, a baler, a harvester, a sprayer, or a harrow, can be connected to the work vehicle **100** for use.

40 [0105] The work vehicle **100** shown in FIG. **9** can be driven by human driving; alternatively, it may only support unmanned driving. In that case, component elements which are only required for human driving, e.g., the cabin **105**, the steering device **106**, and the driver's seat **107** do not need to be provided in the work vehicle **100**. An unmanned work vehicle **100** can travel via autonomous driving, or by remote operation by a user.

45 [0106] FIG. **10** is a block diagram showing an example configuration of the work vehicle **100** and the implement **300**. The work vehicle **100** and the implement **300** can communicate with each other via a communication cable that is included in the linkage device **108**. The work vehicle **100** is able to communicate with the terminal device **400** and the management device **600** via the network **80**.

[0107] In addition to the GNSS unit **110**, the cameras **120**, the obstacle sensors **130**, the LiDAR sensor **140** and the operational terminal **200**, the work vehicle **100** in the example of FIG. **10** includes sensors **150** to detect the operating status of the work vehicle **100**, a control system **160**, a communication device **190**, operation switches **210**, a buzzer **220**, and a drive device **240**. These component elements are communicably connected to each other via a bus. The GNSS unit **110** includes a GNSS receiver **111**, an RTK receiver **112**, an inertial measurement unit (IMU) **115**, and a processing circuit **116**. The sensors **150** include a steering wheel sensor **152**, an angle -of-turn sensor **154**, and an axle sensor **156**. The control system **160** includes a storage device **170** and a controller **180**. The controller **180** includes a plurality of electronic control units (ECU) **181** to **186**. The implement **300** includes a drive device **340**, a controller **380**, and a communication device **390**. Note that FIG. **10** shows component elements which are relatively closely related to the operations of self-driving by the work vehicle **100**, while other components are omitted from illustration.

[0108] The GNSS receiver **111** in the GNSS unit **110** receives satellite signals transmitted from the plurality of GNSS satellites and generates GNSS data based on the satellite signals. The GNSS data is generated in a predetermined format such as, for example, the NMEA-0183 format. The GNSS data may include, for example, the identification number, the angle of elevation, the azimuth angle, and a value representing the reception strength of each of the satellites from which the satellite signals are received.

[0109] The GNSS unit **110** shown in FIG. **10** performs positioning of the work vehicle **100** by utilizing an RTK (Real Time Kinematic)-GNSS. FIG. **11** is a conceptual diagram showing an example of the work vehicle **100** performing positioning based on the RTK-GNSS. In the positioning based on the RTK-GNSS, not only satellite signals transmitted from a plurality of GNSS satellites **50**, but also a correction signal that is transmitted from a reference station **60** is used. The reference station **60** may be disposed near the field where the work vehicle **100** performs tasked travel (e.g., at a position within 10 km of the work vehicle **100**). The reference station **60** generates a correction signal of, for example, an RTCM format based on the satellite signals received from the plurality of GNSS satellites **50**, and transmits the correction signal to the GNSS unit **110**. The RTK receiver **112**, which includes an antenna and a modem, receives the correction signal transmitted from the reference station **60**. Based on the correction signal, the processing circuit **116** of the GNSS unit **110** corrects the results of the positioning performed by use of the GNSS receiver **111**. Use of the RTK-GNSS enables positioning with an accuracy on the order of several centimeters of errors, for example. Positional information including latitude, longitude, and altitude information is acquired through the highly accurate positioning by the RTK-GNSS. The GNSS unit **110**

calculates the position of the work vehicle **100** as frequently as, for example, one to ten times per second.

[0110] Note that the positioning method is not limited to being performed by use of an RTK-GNSS; any arbitrary positioning method (e.g., an interferometric positioning method or a relative positioning method) that provides positional information with the necessary accuracy can be used. For example, positioning may be performed by utilizing a VRS (Virtual Reference Station) or a DGPS (Differential Global Positioning System). In the case where positional information with the necessary accuracy can be obtained without the use of the correction signal transmitted from the reference station **60**, positional information may be generated without using the correction signal. In that case, the GNSS unit **110** does not need to include the RTK receiver **112**.

[0111] Even in the case where the RTK-GNSS is used, at a site where the correction signal from the reference station **60** cannot be acquired (e.g., on a road far from the field), the position of the work vehicle **100** is estimated by another method with no use of the signal from the RTK receiver **112**. For example, the position of the work vehicle **100** may be estimated by matching the data output from the LiDAR sensor **140** and/or the cameras **120** against a highly accurate environment map.

[0112] The GNSS unit **110** according to the present embodiment further includes the IMU **115**. The IMU **115** may include a 3-axis accelerometer and a 3-axis gyroscope. The IMU **115** may include a direction sensor such as a 3-axis geomagnetic sensor. The IMU **115** functions as a motion sensor which can output signals representing parameters such as acceleration, velocity, displacement, and attitude of the work vehicle **100**. Based not only on the satellite signals and the correction signal but also on a signal that is output from the IMU **115**, the processing circuit **116** can estimate the position and orientation of the work vehicle **100** with a higher accuracy. The signal that is output from the IMU **115** may be used for the correction or complementation of the position that is calculated based on the satellite signals and the correction signal. The IMU **115** outputs a signal more frequently than the GNSS receiver **111**. Utilizing this signal that is output highly frequently, the processing circuit **116** allows the position and orientation of the work vehicle **100** to be measured more frequently (e.g., about 10 Hz or above). Instead of the IMU **115**, a 3-axis accelerometer and a 3-axis gyroscope may be separately provided. The IMU **115** may be provided as a separate device from the GNSS unit **110**.

[0113] The cameras **120** are imagers that image the surrounding environment of the work vehicle **100**. Each of the cameras **120** includes an image sensor such as a CCD (Charge Coupled Device) or a CMOS (Complementary Metal Oxide Semiconductor), for example. In addition, each camera **120** may include an optical system including one or more lenses and a signal processing circuit. During travel of the work vehicle **100**, the cameras **120** image the surrounding environment of the work ve-

hicle **100**, and generate image data (e.g., motion picture data). The cameras **120** are able to capture motion pictures at a frame rate of 3 frames/second (fps: frames per second) or greater, for example. The images generated by the cameras **120** may be used by a remote supervisor to check the surrounding environment of the work vehicle **100** with the terminal device **400**, for example. The images generated by the cameras **120** may also be used for the purpose of positioning and/or detection of obstacles. As shown in FIG. 9, the plurality of cameras **120** may be provided at different positions on the work vehicle **100**, or a single camera **120** may be provided. A visible camera(s) to generate visible light images and an infrared camera(s) to generate infrared images may be separately provided. Both of a visible camera(s) and an infrared camera(s) may be provided as cameras for generating images for monitoring purposes. The infrared camera(s) may also be used for detection of obstacles at night-time.

[0114] The obstacle sensors **130** detect objects existing in the surroundings of the work vehicle **100**. Each of the obstacle sensors **130** may include a laser scanner or an ultrasonic sonar, for example. When an object exists at a position within a predetermined distance from one of the obstacle sensors **130**, the obstacle sensor **130** outputs a signal indicating the presence of the obstacle. The plurality of obstacle sensors **130** may be provided at different positions on the work vehicle **100**. For example, a plurality of laser scanners and a plurality of ultrasonic sonars may be disposed at different positions on the work vehicle **100**. Providing such a great number of obstacle sensors **130** can reduce blind spots in monitoring obstacles in the surroundings of the work vehicle **100**.

[0115] The steering wheel sensor **152** measures the angle of rotation of the steering wheel of the work vehicle **100**. The angle - of - turn sensor **154** measures the angle of turn of the front wheels **104F**, which are the steered wheels. Measurement values by the steering wheel sensor **152** and the angle - of - turn sensor **154** are used for steering control by the controller **180**.

[0116] The axle sensor **156** measures the rotational speed, i.e., the number of revolutions per unit time, of an axle that is connected to the wheels **104**. The axle sensor **156** may be a sensor including a magnetoresistive element (MR), a Hall generator, or an electromagnetic pickup, for example. The axle sensor **156** outputs a numerical value indicating the number of revolutions per minute (unit: rpm) of the axle, for example. The axle sensor **156** is used to measure the speed of the work vehicle **100**.

[0117] The drive device **240** includes various types of devices required to cause the work vehicle **100** to travel and to drive the implement **300**; for example, the prime mover **102**, the transmission **103**, the steering device **106**, the linkage device **108** and the like described above. The prime mover **102** may include an internal combustion engine such as, for example, a diesel engine. The drive device **240** may include an electric motor for traction instead of, or in addition to, the internal combustion engine.

[0118] The buzzer **220** is an audio output device to present an alarm sound to alert the user of an abnormality. For example, the buzzer **220** may present an alarm sound when an obstacle is detected during self-driving.

The buzzer **220** is controlled by the controller **180**.

[0119] The storage device **170** includes one or more storage mediums such as a flash memory or a magnetic disc. The storage device **170** stores various data that is generated by the GNSS unit **110**, the cameras **120**, the obstacle sensors **130**, the LiDAR sensor **140**, the sensors **150**, and the controller **180**. The data that is stored by the storage device **170** may include map data on the environment where the work vehicle **100** travels (environment map) and data on a global path (target path) for self-driving. The environment map includes information on a plurality of fields where the work vehicle **100** performs agricultural work and roads around the fields. The environment map may be created by a process of aligning a plurality of types of feature block images as shown in, for example, FIG. 4. Separately from the simple environment map as shown in FIG. 4, a detailed environment map usable for localization performed by use of, for example, the LiDAR sensor **140** or the cameras **120** may be stored in the storage device **170**. The environment map and the target path may be generated by a processor in the management device **600**. The controller **180** according to the present embodiment has a function of generating or editing an environment map and a target path. The controller **180** itself may generate the environment map and the target path, or the controller **180** may edit the environment map and the target path, acquired from the management device **600**, in accordance with the environment where the work vehicle **100** travels. The storage device **170** also stores data on a work plan received by the communication device **190** from the management device **600**. The work plan includes information on a plurality of tasks of agricultural work to be performed by the work vehicle **100** over a plurality of working days. The work plan may be, for example, data on a work schedule including information on the time when the work vehicle **100** is scheduled to perform each task of agricultural work on each of the working days. The storage device **170** also stores a computer program(s) to cause each of the ECUs in the controller **180** to perform various operations described below. Such a computer program (s) may be provided to the work vehicle **100** via a storage medium (e.g., a semiconductor memory, an optical disc, etc.) or through telecommunication lines (e.g., the Internet). Such a computer program(s) may be marketed as commercial software.

[0120] The controller **180** includes the plurality of ECUs. The plurality of ECUs include, for example, the ECU **181** for speed control, the ECU **182** for steering control, the ECU **183** for implement control, the ECU **184** for self-driving control, the ECU **185** for path generation, and the ECU **186** for map generation.

[0121] The ECU **181** controls the prime mover **102**, the transmission **103** and brakes included in the drive device

240, thus controlling the speed of the work vehicle **100**.

[0122] The ECU **182** controls the hydraulic device or the electric motor included in the steering device **106** based on a measurement value of the steering wheel sensor **152**, thus controlling the steering of the work vehicle **100**.

[0123] In order to cause the implement **300** to perform a desired operation, the ECU **183** controls the operations of the three-point link, the PTO shaft and the like that are included in the linkage device **108**. Also, the ECU **183** generates a signal to control the operation of the implement **300**, and transmits this signal from the communication device **190** to the implement **300**.

[0124] Based on data output from the GNSS unit **110**, the cameras **120**, the obstacle sensors **130**, the LiDAR sensor **140** and the sensors **150**, the ECU **184** performs computation and control for achieving self-driving. For example, the ECU **184** specifies the position of the work vehicle **100** based on the data output from at least one of the GNSS unit **110**, the cameras **120** and the LiDAR sensor **140**. Inside the field, the ECU **184** may determine the position of the work vehicle **100** based only on the data output from the GNSS unit **110**. The ECU **184** may estimate or correct the position of the work vehicle **100** based on the data acquired by the cameras **120** or the LiDAR sensor **140**. Use of the data acquired by the cameras **120** or the LiDAR sensor **140** allows the accuracy of the positioning to be further improved. Outside the field, the ECU **184** estimates the position of the work vehicle **100** by use of the data output from the LiDAR sensor **140** or the cameras **120**. For example, the ECU **184** may estimate the position of the work vehicle **100** by matching the data output from the LiDAR sensor **140** or the cameras **120** against the environment map. During self-driving, the ECU **184** performs computation necessary for the work vehicle **100** to travel along a target path or a local path, based on the estimated position of the work vehicle **100**. The ECU **184** sends the ECU **181** a command to change the speed, and sends the ECU **182** a command to change the steering angle. In response to the command to change the speed, the ECU **181** controls the prime mover **102**, the transmission **103** or the brakes to change the speed of the work vehicle **100**. In response to the command to change the steering angle, the ECU **182** controls the steering device **106** to change the steering angle.

[0125] While the work vehicle **100** is traveling along the target path, the ECU **185** consecutively generates a local path along which the work vehicle **100** can avoid an obstacle. During travel of the work vehicle **100**, the ECU **185** recognizes an obstacle existing in the surroundings of the work vehicle **100** based on the data output from the cameras **120**, the obstacle sensors **130** and the LiDAR sensor **140**. The ECU **185** generates a local path such that the work vehicle **100** avoids the recognized obstacle. The ECU **185** may have a function of performing global path planning instead of the management device **160**. In this case, the ECU **185** determines a desti-

nation of the work vehicle **100** based on the work plan stored in the storage device **170**, and determines a target path from a beginning point to a target point of the movement of the work vehicle **100**. For example, the ECU **185** can generate, as the target path, a path by which the work vehicle **100** can arrive at the destination within the shortest time period, based on the environment map stored in the storage device **170** and including information on the roads around the fields.

[0126] The ECU **186** generates or edits a map of the environment where the work vehicle **100** travels. In the present embodiment, an environment map generated by an external device such as the management device **600** is transmitted to the work vehicle **100** and recorded in the storage device **170**. Instead, the ECU **186** can generate or edit an environment map. Hereinafter, an operation in a case where the ECU **186** generates an environment map will be described. An environment map may be generated based on sensor data output from the LiDAR sensor **140**. For generating an environment map, the ECU **186** consecutively generates three-dimensional point cloud data based on the sensor data output from the LiDAR sensor **140** while the work vehicle **100** is traveling. The ECU **186** can generate an environment map by connecting the point cloud data consecutively generated by use of an algorithm such as, for example, SLAM. The environment map generated in this manner is a highly accurate three-dimensional map, and may be used for localization performed by the ECU **184**. Based on this three-dimensional map, a two-dimensional map (e.g., the map of the bitmap format as shown in FIG. 4) usable for the global path planning may be generated. In this specification, the three-dimensional map that is used for the localization and the two-dimensional map that is used for the global path planning will be both referred to as an "environment map". The ECU **186** may further edit the map by adding, to the map, various types of attribute information on a structural body, the state of the road surface, how easily the road is passable, or the like that is recognized based on the data output from the cameras **120** or the LiDAR sensor **140**.

[0127] Through the actions of these ECUs, the controller **180** realizes self-driving. During self-driving, the controller **180** controls the drive device **240** based on the measured or estimated position of the work vehicle **100** and on the target path. As a result, the controller **180** can cause the work vehicle **100** to travel along the target path.

[0128] The plurality of ECUs included in the controller **180** can communicate with each other in accordance with a vehicle bus standard such as, for example, a CAN (Controller Area Network). Instead of the CAN, faster communication methods such as Automotive Ethernet (registered trademark) may be used. Although the ECUs **181** to **186** are illustrated as individual blocks in FIG. 10, the function of each of the ECU **181** to **186** may be implemented by a plurality of ECUs. Alternatively, an onboard computer that integrates the functions of at least some of the ECUs **181** to **186** may be provided. The controller

180 may include ECUs other than the ECUs **181** to **186**, and any number of ECUs may be provided in accordance with functionality. Each ECU includes a processing circuit including one or more processors.

[0129] The communication device **190** is a device including a circuit communicating with the implement **300**, the terminal device **400** and the management device **600**. The communication device **190** includes circuitry to perform exchanges of signals complying with an ISOBUS standard such as ISOBUS-TIM, for example, between itself and the communication device **390** of the implement **300**. This allows the implement **300** to perform a desired operation, or allows information to be acquired from the implement **300**. The communication device **190** may further include an antenna and a communication circuit to exchange signals via the network **80** with communication devices of the terminal device **400** and the management device **600**. The network **80** may include a 3G, 4G, 5G, or any other cellular mobile communications network and the Internet, for example. The communication device **190** may have a function of communicating with a mobile terminal that is used by a supervisor who is situated near the work vehicle **100**. With such a mobile terminal, communication may be performed based on any arbitrary wireless communication standard, e.g., Wi-Fi (registered trademark), 3G, 4G, 5G or any other cellular mobile communication standard, or Bluetooth (registered trademark).

[0130] The operational terminal **200** is a terminal for the user to perform a manipulation related to the travel of the work vehicle **100** and the operation of the implement **300**, and is also referred to as a virtual terminal (VT). The operational terminal **200** may include a display device such as a touch screen panel, and/or one or more buttons. The display device may be a display such as a liquid crystal display or an organic light-emitting diode (OLED) display, for example. By manipulating the operational terminal **200**, the user can perform various manipulations, such as, for example, switching ON/OFF the self-driving mode, recording or editing an environment map, setting a target path, and switching ON/OFF the implement **300**. At least a portion of these manipulations may also be realized by manipulating the operation switches **210**. The operational terminal **200** may be configured so as to be detachable from the work vehicle **100**. A user who is at a remote place from the work vehicle **100** may manipulate the detached operational terminal **200** to control the operation of the work vehicle **100**. Instead of the operational terminal **200**, the user may manipulate a computer on which necessary application software is installed, for example, the terminal device **400**, to control the operation of the work vehicle **100**.

[0131] FIG. 12 is a diagram showing an example of the operational terminal **200** and an example of the operation switches **210** both provided in the cabin **105**. In the cabin **105**, the operation switches **210**, including a plurality of switches that are manipulable to the user, are disposed. The operation switches **210** may include, for example, a

switch to select the gear shift as to a main gear shift or a range gear shift, a switch to switch between a self-driving mode and a manual driving mode, a switch to switch between forward travel and backward travel, a switch to raise or lower the implement **300**, and the like. In the case where the work vehicle **100** only performs unmanned driving and lacks human driving functionality, the work vehicle **100** does not need to include the operation switches **210**.

[0132] The drive device **340** in the implement **300** shown in FIG. 10 performs operations necessary for the implement **300** to perform predetermined work. The drive device **340** includes a device suitable to uses of the implement **300**, for example, a hydraulic device, an electric motor, a pump or the like. The controller **380** controls the operation of the drive device **340**. In response to a signal that is transmitted from the work vehicle **100** via the communication device **390**, the controller **380** causes the drive device **340** to perform various operations. Moreover, a signal that is in accordance with the state of the implement **300** can be transmitted from the communication device **390** to the work vehicle **100**.

[0133] Now, a configuration of the management device **600** and the terminal device **400** will be described with reference to FIG. 13. FIG. 13 is a block diagram showing an example of schematic hardware configuration of the management device **600** and the terminal device **400**.

[0134] The management device **600** includes a storage device **650**, a processor **660**, a ROM (Read Only Memory) **670**, a RAM (Random Access Memory) **680**, and a communication device **690**. These component elements are communicably connected to each other via a bus. The management device **600** may function as a cloud server to manage the schedule of the agricultural work to be performed by the work vehicle **100** in a field and support agriculture by use of the data managed by the management device **600** itself. The user can input information necessary to create a work plan by use of the terminal device **400** and upload the information to the management device **600** via the network **80**. The management device **600** can create a schedule of agricultural work, that is, a work plan based on the information. The management device **600** can further generate or edit an environment map and perform global path planning for the work vehicle **100**.

[0135] The communication device **690** is a communication module to communicate with the work vehicle **100** and the terminal device **400** via the network **80**. The communication device **690** can perform wired communication in compliance with communication standards such as, for example, IEEE1394 (registered trademark) or Ethernet (registered trademark). The communication device **690** may perform wireless communication in compliance with Bluetooth (registered trademark) or Wi-Fi, or cellular mobile communication based on 3G, 4G, 5G or any other cellular mobile communication standard.

[0136] The processor **660** may be, for example, a semiconductor integrated circuit including a central process-

ing unit (CPU). The processor **660** may be realized by a microprocessor or a microcontroller. Alternatively, the processor **660** may be realized by an FPGA (Field Programmable Gate Array), a GPU (Graphics Processing Unit), an ASIC (Application Specific Integrated Circuit) or an ASSP (Application Specific Standard Product) each including a CPU, or a combination of two or more selected from these circuits. The processor **660** consecutively executes a computer program, describing commands to execute at least one process, stored in the ROM **670** and thus realizes a desired process.

[0137] The ROM **670** is, for example, a writable memory (e.g., PROM), a rewritable memory (e.g., flash memory) or a memory which can only be read from but cannot be written to. The ROM **670** stores a program to control operations of the processor **660**. The ROM **670** does not need to be a single storage medium, and may be an assembly of a plurality of storage mediums. A portion of the assembly of the plurality of storage memories may be a detachable memory.

[0138] The RAM **680** provides a work area in which the control program stored in the ROM **670** is once developed at the time of boot. The RAM **680** does not need to be a single storage medium, and may be an assembly of a plurality of storage mediums.

[0139] The storage device **650** mainly functions as a storage for a database. The storage device **650** may be, for example, a magnetic storage device or a semiconductor storage device. An example of the magnetic storage device is a hard disc drive (HDD). An example of the semiconductor storage device is a solid state drive (SSD). The storage device **650** may be a device independent from the management device **600**. For example, the storage device **650** may be a storage device connected to the management device **600** via the network **80**, for example, a cloud storage.

[0140] The terminal device **400** includes an input device **420**, a display device **430**, a storage device **450**, a processor **460**, a ROM **470**, a RAM **480**, and a communication device **490**. These component elements are communicably connected to each other via a bus. The input device **420** is a device to convert an instruction from the user into data and input the data to a computer. The input device **420** may be, for example, a keyboard, a mouse or a touch panel. The display device **430** may be, for example, a liquid crystal display or an organic EL display. The processor **460**, the ROM **470**, the RAM **480**, the storage device **450** and the communication device **490** are substantially the same as the corresponding component elements described above regarding the example of the hardware configuration of the management device **600**, and will not be described again.

[2. Operation]

[0141] Now, an operation of the work vehicle **100**, the terminal device **400** and the management device **600** will be described.

[2-1. Self-traveling operation]

[0142] First, an example operation of self-traveling of the work vehicle **100** will be described. The work vehicle **100** according to the present embodiment can automatically travel both inside and outside a field. Inside the field, the work vehicle **100** drives the implement **300** to perform predetermined agricultural work while traveling along a preset target path. When detecting an obstacle by the obstacle sensors **130** thereof while traveling inside the field, the work vehicle **100** halts traveling and performs operations of presenting an alarm sound from the buzzer **220**, transmitting an alert signal to the terminal device **400** and the like. Inside the field, the positioning of the work vehicle **100** is performed based mainly on data output from the GNSS unit **110**. Meanwhile, outside the field, the work vehicle **100** automatically travels along a target path set for an agricultural road or a general road outside the field. The processor **660** of the management device **600** generates the map as shown in FIG. 4 as an example, by a process of aligning one or more types of feature block images, and sets a target path on a road on the map. While traveling outside the field, the work vehicle **100** performs local path planning based on data acquired by the cameras **120** or the LiDAR **140**. When an obstacle is detected outside the field, the work vehicle **100** avoids the obstacle or halts at the point. Outside the field, the position of the work vehicle **100** is estimated based on data output from the LiDAR sensor **140** or the cameras **120** in addition to positioning data output from the GNSS unit **110**.

[0143] Hereinafter, an operation of the work vehicle **100** performing self-traveling inside the field will be described. An operation of the work vehicle **100** performing self-traveling outside the field and a process of global path planning and local path planning outside the field will be described later.

[0144] FIG. 14 is a diagram schematically showing an example of the work vehicle **100** automatically traveling along a target path in a field. In this example, the field includes a work area **72**, in which the work vehicle **100** performs work by using the implement **300**, and headlands **74**, which are located near outer edges of the field. The user may previously specify which regions of the field on the map would correspond to the work area **72** and the headlands **74**. The target path in this example includes a plurality of main paths **P1** parallel to each other and a plurality of turning paths **P2** interconnecting the plurality of main paths **P1**. The main paths **P1** are located in the work area **72**, whereas the turning paths **P2** are located in the headlands **74**. Although each of the main paths **P1** in FIG. 14 is illustrated as a linear path, each main path **P1** may also include a curved portion(s). Broken lines in FIG. 14 depict the working breadth of the implement **300**. The working breadth is previously set and recorded in the storage device **170**. The working breadth may be set and recorded by the user manipulating the operational terminal **200** or the terminal device

400. Alternatively, the working breadth may be automatically recognized and recorded when the implement **300** is connected to the work vehicle **100**. The interval between the plurality of main paths **P1** may be set so as to be matched to the working breadth. The target path may be generated based on the manipulation made by the user, before self-driving is begun. The target path may be generated so as to cover the entire work area **72** in the field, for example. Along the target path shown in FIG. **14**, the work vehicle **100** automatically travels while repeating a reciprocating motion from a beginning point of work to an ending point of work. Note that the target path shown in FIG. **14** is merely an example, and the target path may be arbitrarily determined.

[0145] Now, an example control by the controller **180** during self-driving inside the field will be described.

[0146] FIG. **15** is a flowchart showing an example operation of steering control to be performed by the controller **180** during self-driving. During travel of the work vehicle **100**, the controller **180** performs automatic steering by performing the operation from steps **S121** to **S125** shown in FIG. **15**. The speed of the work vehicle **100** will be maintained at a previously-set speed, for example. First, during travel of the work vehicle **100**, the controller **180** acquires data representing the position of the work vehicle **100** that is generated by the GNSS unit **110** (step **S121**). Next, the controller **180** calculates a deviation between the position of the work vehicle **100** and the target path (step **S122**). The deviation represents the distance between the position of the work vehicle **100** and the target path at that moment. The controller **180** determines whether the calculated deviation in position exceeds the previously-set threshold or not (step **S123**). If the deviation exceeds the threshold, the controller **180** changes a control parameter of the steering device included in the drive device **240** so as to reduce the deviation, thus changing the steering angle (step **S124**). If the deviation does not exceed the threshold at step **S123**, the operation of step **S124** is omitted. At the following step **S125**, the controller **180** determines whether a command to end the operation has been received or not. The command to end the operation may be given when the user has instructed that self-driving be suspended through remote operations, or when the work vehicle **100** has arrived at the destination, for example. If the command to end the operation has not been given, the control returns to step **S121** and the controller **180** performs substantially the same operation based on a newly measured position of the work vehicle **100**. The controller **180** repeats the operation from steps **S121** to **S125** until a command to end the operation is given. The aforementioned operation is executed by the ECUs **182** and **184** in the controller **180**.

[0147] In the example shown in FIG. **15**, the controller **180** controls the drive device **240** based only on the deviation between the position of the work vehicle **100** as identified by the GNSS unit **110** and the target path. Alternatively, a deviation in terms of directions may further

be considered in the control. For example, when a directional deviation exceeds a previously-set threshold, where the directional deviation is an angle difference between the orientation of the work vehicle **100** as identified by the GNSS unit **110** and the direction of the target path, the controller **180** may change the control parameter of the steering device of the drive device **240** (e.g., steering angle) in accordance with the deviation.

[0148] Hereinafter, with reference to FIGS. **16A** to **16D**, an example of steering control by the controller **180** will be described more specifically.

[0149] FIG. **16A** is a diagram showing an example of the work vehicle **100** traveling along a target path **P**. FIG. **16B** is a diagram showing an example of the work vehicle **100** at a position which is shifted rightward from the target path **P**. FIG. **16C** is a diagram showing an example of the work vehicle **100** at a position which is shifted leftward from the target path **P**. FIG. **16D** is a diagram showing an example of the work vehicle **100** oriented in an inclined direction with respect to the target path **P**. In these figures, the pose, i.e., the position and orientation, of the work vehicle **100** as measured by the GNSS unit **110** is expressed as $r(x,y,\theta)$. Herein, (x,y) are coordinates representing the position of a reference point on the work vehicle **100** in an XY coordinate system, which is a two-dimensional coordinate system fixed to the globe. In the examples shown in FIGS. **16A** to **16D**, the reference point on the work vehicle **100** is at a position, on the cabin, where a GNSS antenna is disposed, but the reference point may be at any arbitrary position. θ is an angle representing the measured orientation of the work vehicle **100**. Although the target path **P** is shown parallel to the Y axis in the examples illustrated in these figures, the target path **P** may not necessarily be parallel to the Y axis, in general.

[0150] As shown in FIG. **16A**, in the case where the position and orientation of the work vehicle **100** are not deviated from the target path **P**, the controller **180** maintains the steering angle and speed of the work vehicle **100** without changing them.

[0151] As shown in FIG. **16B**, when the position of the work vehicle **100** is shifted rightward from the target path **P**, the controller **180** changes the steering angle so that the traveling direction of the work vehicle **100** will be inclined leftward, thus bringing the work vehicle **100** closer to the path **P**. At this point, not only the steering angle but also the speed may be changed. The magnitude of the steering angle may be adjusted in accordance with the magnitude of a positional deviation Δx , for example.

[0152] As shown in FIG. **16C**, when the position of the work vehicle **100** is shifted leftward from the target path **P**, the controller **180** changes the steering angle so that the traveling direction of the work vehicle **100** will be inclined rightward, thus bringing the work vehicle **100** closer to the path **P**. In this case, too, not only the steering angle but also the speed may be changed. The amount of change of the steering angle may be adjusted in accordance with the magnitude of the positional deviation

Δx , for example.

[0153] As shown in FIG. 16D, in the case where the position of the work vehicle 100 is not considerably deviated from the target path P but its orientation is nonetheless different from the direction of the target path P, the controller 180 changes the steering angle so that the directional deviation $\Delta\theta$ will become smaller. In this case, too, not only the steering angle but also the speed may be changed. The magnitude of the steering angle may be adjusted in accordance with the magnitudes of the positional deviation Δx and the directional deviation $\Delta\theta$, for example. For instance, the amount of change of the steering angle (which is in accordance with the directional deviation $\Delta\theta$) may be increased as the absolute value of the positional deviation Δx decreases. When the positional deviation Δx has a large absolute value, the steering angle will be changed greatly in order for the work vehicle 100 to return to the path P, so that the directional deviation $\Delta\theta$ will inevitably have a large absolute value. Conversely, when the positional deviation Δx has a small absolute value, the directional deviation $\Delta\theta$ needs to become closer to zero. Therefore, it may be advantageous to introduce a relatively large weight (i. e. , control gain) for the directional deviation $\Delta\theta$ in determining the steering angle.

[0154] For the steering control and speed control of the work vehicle 100, control techniques such as PID control or MPC (Model Predictive Control) may be applied. Applying these control techniques will make for smoothness of the control of bringing the work vehicle 100 closer to the target path P.

[0155] Note that, when an obstacle is detected by one or more obstacle sensors 130 during travel, the controller 180 halts the work vehicle 100. At this point, the controller 180 may cause the buzzer 220 to present an alarm sound or may transmit an alert signal to the terminal device 400. In the case where the obstacle is avoidable, the controller 180 may control the drive device 240 such that the obstacle is avoided.

[0156] The work vehicle 100 according to the present embodiment can perform self-traveling outside a field as well as inside the field. Outside the field, the controller 180 is able to detect an object located at a relatively distant position from the work vehicle 100 (e.g. , another vehicle, a pedestrian, etc.) based on data output from the cameras 120 or the LiDAR sensor 140. The controller 180 generates a local path such that the local path avoids the detected object, and performs speed control and steering control along the local path. In this manner, self-traveling on a road outside the field can be realized.

[0157] As described above, the work vehicle 100 according to the present embodiment can automatically travel inside the field and outside the field in an unmanned manner. FIG. 17 is a diagram schematically showing an example of state where a plurality of the work vehicles 100 are performing self-traveling inside a field 70 and on a road 76 outside the field 70. In the storage device 170, an environment map of a region including a plurality of

fields and roads around the fields, and a target path, are recorded. The environment map and the target path may be generated by the management device 600 or the ECU 185. In the case of traveling on a road, the work vehicle 100 travels along the target path while sensing the surroundings thereof by use of the sensing devices such as the cameras 120 and the LiDAR sensor 140, with the implement 300 being raised. During travel, the controller 180 consecutively generates a local path and causes the work vehicle 100 to travel along the local path. This allows the work vehicle 100 to perform self-traveling while avoiding obstacles. During travel, the target path may be changed in accordance with the state.

15 [2-2. Creation of a work plan]

[0158] The work vehicle 100 according to the present embodiment automatically moves between the fields and performs agricultural work in each of the fields in accordance with a work plan created by the management device 600. The work plan includes information on one or more tasks of agricultural work to be performed by the work vehicle 100. For example, the work plan includes information on one or more tasks of agricultural work to be performed by the work vehicle 100 and on the field where each task is to be performed. The work plan may include information on a plurality of tasks of agricultural work to be performed by the work vehicle 100 over a plurality of working days and on the field where each task of agricultural work is to be performed. More specifically, the work plan may be a database including information on a work schedule indicating which agricultural machine is to perform which task of agricultural work in which field at which point of time for each working day. The work plan may be created by the processor 660 of the management device 600 based on information input by the user to the terminal device 400.

[0159] FIG. 18 is a table showing an example of schedule of agricultural work created by the management device 600. The schedule in this example includes information representing the date and time of the agricultural work, the field for the agricultural work, the contents of the work, and the implement to be used, for each of the registered agricultural machines. The schedule may include, in addition to the information shown in FIG. 18, other information in accordance with the contents of work, for example, information on the types of agricultural chemicals or the spray amounts of the agricultural chemicals, . The processor 660 of the management device 600 instructs the work vehicle 100 to perform the agricultural work in accordance with such a schedule. The schedule may be downloaded by the controller 180 of the work vehicle 100 and may also stored in the storage device 170. In this case, the controller 180 may spontaneously begin the operation in accordance with the schedule stored in the storage device 170.

[0160] In the present embodiment, the work plan is created by the management device 600. The work plan may

be created by another device. For example, the processor **460** of the terminal device **400** or the controller **180** of the work vehicle **100** may have a function of creating or updating the work plan.

[2-3. Path planning]

[0161] Now, an operation of path planning according to the present embodiment will be described in more detail.

[0162] The management device **600** and the control system **160** of the work vehicle **100** according to the present embodiment cooperate with each other to function as a path planning system for the work vehicle **100**. The storage device **650** stores a map including a plurality of fields and roads around the fields. The processor **660** of the management device **600** functions as a processing unit that generates a map and generates a path for the work vehicle **100** on the map. The management device **600** generates a path for the work vehicle **100** based on the map and a work plan. Note that a portion of, or the entirety of, a map generation process and a path generation process, which are to be performed by the management device **600**, may be performed by the ECU **185** of the controller **180** of the work vehicle **100**. Alternatively, a portion of, or the entirety of, the map generation process and the path generation process, which are to be performed by the management device **600**, may be performed by the operational terminal **200** of the work vehicle **100** or the terminal device **400**.

[0163] FIG. **19** is a diagram showing an example of map that is referred to at the time of path planning. This map is a two-dimensional digital map, and may be created or updated by the management device **600** or the ECU **185**. The map may be generated by the method described above with reference to FIG. **1** to FIG. **7**. In the present embodiment, before performing self-traveling, the work vehicle **100** may collect data for map generation by use of the LiDAR sensor **140** and the cameras **120** while traveling, by manual driving, along the path along which the work vehicle **100** is to travel. The map shown in FIG. **19** includes information on the position of each of points (e.g., the latitude and the longitude of each of the points) in a plurality of fields **70** where the work vehicle **100** is to perform agricultural work and roads **76** around the fields **70**. The map in this example further includes positional information on a repository **90** for the work vehicle **100** and on a waiting area **96**, where the work vehicle **100** is to wait temporarily. The repository **90** and the waiting area **96** may be registered by a manipulation performed by the user by use of the terminal device **400**. The map as shown in FIG. **19** may be created for the entirety of a region where the work vehicle **100** may travel. Note that the map shown in FIG. **19** is a two-dimensional map, but a three-dimensional map may be used for the path planning.

[0164] The repository **90** may be, for example, a garage, a barn or a parking area adjacent to a house or an

office of the user. The waiting area **96** may be, for example, a site that is managed or used jointly by a plurality of users. The waiting area **96** may be a facility such as a parking area or a garage managed or run by a regional government of a city, a town or a village, an agricultural cooperative or a corporation. In the case where the waiting area **96** is a facility locked at nighttime, the work vehicle **100** in the waiting area **96** can be prevented from being robbed. FIG. **19** shows one waiting area **96** as an example, but a plurality of waiting areas **96** may be provided. In the case where the work vehicle **100** moves around within a relatively small range, there is no need to provide the waiting area **96** separately from the repository **90**.

[0165] Before the agricultural work begins on each of working days, the management device **600** reads, from the storage device **650**, a map of a region including the field(s) where the agricultural work is to be scheduled on that working day, and generates a path for the work vehicle **100** based on the map. More specifically, the management device **600** generates a first path, along which the work vehicle **100** is to travel while performing the agricultural work inside a field **70** (the first path is also referred to as a "tasked travel path"), on the field on the map, and generates a second path, along which the work vehicle **100** is to travel toward the field **70**, on a road on the map. After generating the first path and the second path, the management device **600** connects the first path and the second path to each other to generate a global path for the work vehicle **100**.

[0166] FIG. **20** is a diagram showing an example of global path to be generated. In FIG. **20**, paths, of the global path generated by the management device **600**, which are generated on the roads **76** are represented by arrows. The first paths (i.e., tasked travel paths) generated inside the fields **70** are omitted. The tasked travel path is, for example, the path as shown in FIG. **14**, and is connected to a second path generated on the roads **76**. The arrows shown in FIG. **20** represent an example of paths for the work vehicle **100** on one working day.

[0167] In the example shown in FIG. **20**, the management device **600** generates, as a path for one working day, a path along which the work vehicle **100** departs from the repository **90**, sequentially passes eight fields **70** and reaches the waiting area **96**. This is because the waiting area **96** is the waiting area closest to the field group, where the agricultural work is scheduled to be performed on the next working day. In the case where the group of fields where the agricultural work is to be scheduled to be performed on the next working day is close to the repository **90**, the management device **600** may return the work vehicle **100** to the repository **90** after the agricultural work for the day ends. In this manner, the management device **600** may generate a path from the field where the final task of agricultural work is to be performed on each working day, to the waiting area **96** located at the shortest average distance from the group of fields where the agricultural work is to be performed on

the next working day. The work vehicle **100** travels along the generated path.

[0168] In the example shown in FIG. **20**, on one working day, the work vehicle **100** departs from the repository **90**, and sequentially visits the fields in the field group, where the agricultural work is scheduled to be performed on the day, and performs the agricultural work indicated by the schedule in each field. In each field, the work vehicle **100** performs the agricultural work while performing self-traveling along the tasked travel path by, for example, the method described above with reference to FIG. **14** to FIG. **16D**. When the agricultural work ends in one field, the work vehicle **100** enters the next field, and performs the agricultural work in substantially the same manner. The work vehicle **100** operates in this manner, and when the agricultural work ends in the field assigned to the final task of agricultural work for the day, the work vehicle **100** moves to the waiting area **96**. The work vehicle **100** waits at the waiting area **96** until the next working day. On the next working day, the work vehicle **100** departs from the waiting area **96** and sequentially visits the fields in the field group, where the agricultural work is scheduled to be performed on the day, and performs the agricultural work indicated by the schedule in each field. With such an operation, the work vehicle **100** is moved efficiently along an optimal path in accordance with the schedule, so that the scheduled agricultural work can be completed.

[0169] There may be a case where while the work vehicle **100** is traveling outside the field, there is an obstacle such as a pedestrian or another vehicle on the global path or in the vicinity thereof. In order to avoid the work vehicle **100** colliding against the obstacle, while the work vehicle **100** is traveling, the ECU **185** of the controller **180** consecutively generates a local path along which the work vehicle **100** can avoid the obstacle. While the work vehicle **100** is traveling, the ECU **185** generates a local path based on sensing data acquired by the sensing device included in the work vehicle **100** (the obstacle sensors **130**, the LiDAR sensor **140**, the cameras **120**, etc.). The local path is defined by a plurality of waypoints along a portion of the global path. Based on the sensing data, the ECU **185** determines whether or not there is an obstacle existing on the road on which the work vehicle **100** is proceeding or in the vicinity thereof. In the case where there is such an obstacle, the ECU **185** sets a plurality of waypoints such that the obstacle is avoided, and thus generates a local path. In the case where there is no such obstacle, the ECU **185** generates a local path substantially parallel to the global path. Information representing the generated local path is transmitted to the ECU **184** responsible for self-driving control. The ECU **184** controls the ECU **181** and the ECU **182** such that the work vehicle **100** travels along the local path. This allows the work vehicle **100** to travel while avoiding the obstacle. In the case where there is a traffic signal on the road on which the work vehicle **100** is traveling, the work vehicle **100** may recognize the traffic signal based on,

for example, an image captured by the cameras **120** and perform an operation of halting at a red light and moving forward at a green light.

[0170] FIG. **21** is a diagram showing an example of global path and an example of local path generated in an environment where there is an obstacle. FIG. **21** represents, as an example, a global path **31** by the broken line arrows, and represents, as an example, local paths **32** consecutively generated during travel of the work vehicle **100** by the solid line arrows. The global path **31** is defined by a plurality of waypoints **31p**. The local paths **32** are defined by a plurality of waypoints **32p** set at a shorter interval than the waypoints **31p**. The waypoints each have information on, for example, the position and the orientation. The management device **600** sets the plurality of waypoints **31p** at a plurality of points including an intersection of the roads **76** to generate the global path **31**. The interval between the waypoints **31p** is relatively long, and may be, for example, about several meters to about several tens of meters. The ECU **185** sets the plurality of waypoints **32p** based on the sensing data output from the sensing device during travel of the work vehicle **100** to generate the local paths **32**. The interval between the waypoints **32p** of the local paths **32** is shorter than the interval between the waypoints **31p** of the global path **31**. The interval between the waypoints **32p** may be, for example, about several tens of centimeters (cm) to about several meters (m). The local paths **32** are generated in a relatively small range (e.g., a range of about several meters) from the position of the work vehicle **100**. FIG. **21** shows, as an example, a series of local paths **32** generated while the work vehicle **100** travels along the road **76** between the fields **70** and turns left at the intersection. While the work vehicle **100** is moving, the ECU **185** repeats an operation of generating a local path from the position of the work vehicle **100** estimated by the ECU **184** to, for example, a point frontward of the work vehicle **100** by several meters. The work vehicle **100** travels along the local paths consecutively generated.

[0171] In the example shown in FIG. **21**, there is an obstacle **40** (e.g., a human) frontward of the work vehicle **100**. FIG. **21** shows a fan-shaped region as an example of range sensed by the sensing devices such as the cameras **120**, the obstacle sensors **130** or the LiDAR sensor **140** mounted on the work vehicle **100**. In such a state, the ECU **185** generates the local paths **32** such that the obstacle **40** detected based on the sensing data is avoided. The ECU **185** determines whether or not there is a possibility that the work vehicle **100** will collide against the obstacle **40**, based on, for example, the sensing data and the width of the work vehicle **100** (including the width of the implement in the case where the implement is attached). In the case where there is a possibility that the work vehicle **100** will collide against the obstacle **40**, the ECU **185** sets the plurality of waypoints **32p** such that the obstacle **40** is avoided, and generates the local paths **32**. Note that the ECU **185** may recognize the state of the road surface (e.g., being muddy, having a cave-in,

etc.) based on the sensing data, in addition to the presence/absence of the obstacle **40**, and in the case where a site on which it is difficult to walk is detected, may generate the local paths **32** such that the local path **32** avoids such a site. The work vehicle **100** travels along the local paths **32**. In the case where the obstacle **40** cannot be avoided in whichever manner the local paths **32** may be set, the controller **180** may halt the work vehicle **100**. At this point, the controller **180** may transmit an alert signal to the terminal device **400** to warn a supervisor. In the case where after the work vehicle **100** halts, the obstacle **40** is moved and it is recognized that there is no risk of collision, the controller **180** may restart the travel of the work vehicle **100**.

[2-4. Update of the map]

[0172] As described above, the global path planning is performed based on the map of the environment where the work vehicle **100** is to travel. The map includes positional information on a plurality of fields in a region where the work vehicle **100** is to travel and the roads around the fields. The map may further include information representing the distribution of features existing around the roads (e.g., grass, tree, waterway, building, etc.). The information representing these features may be generated based on data acquired by the sensing device such as the LiDAR sensor or the camera while the work vehicle **100** or any other movable body is traveling. In an environment where the plants grow thick along a road or a high building is built around the road, receipt of radio waves from a GNSS satellite or travel of the work vehicle **100** may possibly be prevented. In, for example, an environment where there are trees at a high density around an agricultural road, leaves growing thick high up in the trees form a canopy and act as an obstacle or a multi - reflector against the radio waves from a satellite. For such an agricultural road, it is difficult to perform accurate positioning by GNSS. In order to avoid generation of a path on such a road, the ECU **186** may recognize a structural body based on the sensing data acquired by the sensing device while the work vehicle **100** is performing self - traveling, and reflect the recognized structural body on the map. The structural body to be recognized may be, for example, a tree, a building, a waterway, a road sign or the like. The ECU **186** may further recognize at least one of: the state of the road on which the work vehicle **100** is traveling and the state of the plants in the surroundings of the work vehicle **100**, based on the sensing data, and reflect the recognized state on the map.

[0173] As in the above-described example, in an environment where plants grow thick around the roads, the state of the plants change season by season, and therefore, the ease of passing along the roads may change. For example, in summer rather than in winter, the ratio of the portions of the roads that are covered with the plants is higher, and the number of roads that are difficult

to pass along tends to be larger. In this situation, the ECU **186** may generate a plurality of maps in accordance with the seasons and store the maps in the storage device **170**. For example, the ECU **186** may generate four types of maps for spring, summer, autumn and winter. In these maps, geographical information on the fields, the roads, the waiting areas, the buildings and the like is common, but attribute information on the growing state of the plants or on whether or not it is possible to pass along the roads may be different. The plurality of maps thus generated are transmitted to the management device **600** and recorded in the storage device **650**. The management device **600** may extract the map, corresponding to the season when the agricultural work is to be performed, from the recorded plurality of maps, and generate a path for the work vehicle **100** based on the extracted map. This allows appropriate global path planning in accordance with the season to be realized.

20 (Other embodiments)

[0174] The configurations and operations in the above-described embodiments are merely examples, and the present disclosure is not limited to the above-described embodiments. Hereinafter, other example embodiments will be described.

[0175] In the above-described embodiments, the processor **660** of the management device **600** creates a work plan, generates an environment map, and performs global path planning for the work vehicle **100**, whereas the controller **180** disposed inside the work vehicle **100** performs local path planning and travel control for the work vehicle **100**. Alternatively, a portion of the operations assigned to the management device **600** may be performed by the controller **180**, the operational terminal **200** or the terminal device **400**. For example, the generation of the environment map and the generation of the global path may be performed by the controller **180**, the operational terminal **200** or the terminal device **400**.

[0176] The management device **600** may manage the operations of a plurality of agricultural machines including the work vehicle **100**. In this case, the management device **600** may perform global path planning and issue travel instructions for each of the agricultural machines based on the schedule of the agricultural work to be performed by each agricultural machine.

[0177] A system performing map generation, path planning or self-driving control according to the above-described embodiments can be mounted on an agricultural machine lacking such functions, as an add-on. Such a system may be manufactured and marketed independently from the agricultural machine. A computer program for use in such a system may also be manufactured and marketed independently from the agricultural machine. The computer program may be provided in a form stored in a non-transitory computer-readable storage medium, for example. The computer program may also be provided through downloading via telecommunication lines

(e.g., the Internet).

[0178] As described above, a map generation system according to an embodiment of the present disclosure generates map data for an agricultural machine automatically traveling on a road around a field. The map generation system includes a storage device to store a plurality of feature block images respectively associated with a plurality of types of features existing around the road, and a processing unit. The processing unit acquires position distribution data on one or more types of features existing around the road, the position distribution data being generated based on at least one of sensor data from a LiDAR sensor and image data from an imager, the sensor data and the image data being output while a movable body including at least one of the LiDAR sensor and the imager is moving along the road; reads, from the storage device, one or more types of feature block images associated with the one or more types of features; and aligns the feature block images in accordance with the position distribution data to generate map data on a region including the road.

[0179] According to the above-described configuration, map data suitable to, for example, path planning for the agricultural machine automatically traveling on the road around the field can be efficiently generated.

[0180] The processing unit may display, on a display screen, a graphical user interface (GUI) to set a width and a height of each of the plurality of feature block images, and align the one or more types of feature block images each having the width and the height set on the GUI to generate the map data.

[0181] According to the above-described configuration, the manager of the system or the user of the agricultural machine can set the width and the height of each feature block image on the GUI. As a result, the feature block image can be set to have an appropriate size in accordance with the type of the feature, and a preferred map can be easily generated.

[0182] The processing unit may generate the map data by a process including the following steps (S11) to (S14) regarding each of the one or more types of features.

(S11): Determine a length in a transverse direction, corresponding to a direction of the width, and a length in a longitudinal direction, corresponding to a direction of the height, of a region occupied by the feature, based on the position distribution data.

(S12): Divide the length in the transverse direction by the width of the feature block image corresponding to the feature to determine a transverse number of the feature block images.

(S13): Divide the length in the longitudinal direction by the height of the feature block image to determine a longitudinal number of the feature block images.

(S14): Align the feature block images by the transverse number in the transverse direction, and aligns the feature block images by the longitudinal number in the longitudinal direction.

[0183] As a result of the above-described process, the feature block images corresponding the features are aligned appropriately in accordance with the length, in each of the transverse direction and the longitudinal direction, of a series of regions occupied by each of the features, and thus a map can be generated. The processing unit may apply the above-described process in a state where the series of regions occupied by each feature is divided into a plurality of rectangular or strip-shaped regions. As a result of such a process, the feature block images can be aligned appropriately regardless of the shapes of the regions occupied by the features.

[0184] The processing unit may recognize the one or more types of features existing around the road based on at least one of the sensor data and the image data, and generate the position distribution data on the one or more types of features based on GNSS data output from a GNSS receiver included in the movable body and the sensor data.

[0185] According to the above-described configuration, the processing unit itself can generate the position distribution data, and generate the map data based on the position distribution data and the one or more types of feature block images.

[0186] The processing unit may recognize the one or more types of features including at least one type among grass, tree, ditch, waterway, field and building existing around the road based on at least one of the sensor data and the image data, and align the one or more types of feature block images, associated with the recognized one or more types of features, in a region where the features exist on the map data, in accordance with the position distribution data, to generate the map data.

[0187] According to the above-described configuration, map data based on the one or more types of feature block images corresponding to at least one type among grass, tree, ditch, waterway, field and building can be generated. As a result, preferred map data reflecting the types and the positional arrangement of the features around the road on which the agricultural machine is to travel can be generated.

[0188] The processing unit may recognize the one or more types of features existing around the road by pattern matching or segmentation based on the image data.

[0189] According to the above-described process, the features can be recognized more correctly based on the image data.

[0190] The processing unit may detect a width of the road based on at least one of the sensor data and the image data, and generate the map data reflecting the width of the road.

[0191] According to the above-described process, map data reflecting the width of the road more correctly can be generated. Therefore, a process of path planning or the like based on the map data can be performed more appropriately.

[0192] The processing unit may detect a border between the road and the one or more types of features

based on at least one of the sensor data and the image data, and align the one or more types of feature block images, associated with the one or more types of features, along, and outward of, the border and dispose an image representing the road inward of the border, to generate the map data.

[0193] According to the above-described process, even in the case where the feature block image corresponding to the road is not prepared, preferred map data can be generated.

[0194] The processing unit may generate the position distribution data representing a distribution of latitudes and longitudes of the one or more types of features based on the GNSS data and the sensor data.

[0195] As a result, map data reflecting the distribution of the latitudes and the longitudes of the one or more types of features more correctly can be generated based on the position distribution data.

[0196] The storage device may store a plurality of pixel art images, respectively representing the plurality of types of features, as the plurality of feature block images. The processing unit may align the pixel art images to generate the map data.

[0197] As a result, small-sized map data represented by the pixel art images can be efficiently generated.

[0198] The storage device may store a road block image associated with the road, as one of the plurality of feature block images. The processing unit may align the one or more types of feature block images associated with the one or more types of features other than the road, and the road block image associated with the road, in accordance with the position distribution data to generate the map data.

[0199] According to the above-described process, the road block image and the other feature block images can be aligned to generate preferred map data.

[0200] The processing unit may generate a path for self-traveling of the agricultural machine along the road based on the map data. The processing unit may transmit data representing the path to the agricultural machine.

[0201] The map generation system may further include a LiDAR sensor and the imager.

[0202] The map generation system may further include the movable body.

[0203] The movable body may be the agricultural machine. The movable body may be different from the agricultural machine.

[0204] A map generation method according to another embodiment of the present disclosure is to generate map data for an agricultural machine automatically traveling on a road around a field. The map generation method includes: acquiring position distribution data on one or more types of features existing around the road, the position distribution data being generated based on at least one of sensor data from a LiDAR sensor and image data from an imager, the sensor data and the image data being output while a movable body including at least one of the LiDAR sensor and the imager is moving along the road;

reading, from a storage device, one or more types of feature block images associated with the one or more types of features; and aligning the feature block images in accordance with the position distribution data to generate map data on a region including the road.

[0205] A map generation program according to still another embodiment of the present disclosure is a computer program to generate map data for an agricultural machine automatically traveling on a road around a field. The program is stored in a computer-readable non-transitory storage medium. The program causes a computer to execute: acquiring position distribution data on one or more types of features existing around the road, the position distribution data being generated based on at least one of sensor data from a LiDAR sensor and image data from an imager, the sensor data and the image data being output while a movable body including at least one of the LiDAR sensor and the imager is moving along the road; reading, from a storage device, one or more types of feature block images associated with the one or more types of features; and aligning the feature block images in accordance with the position distribution data to generate map data on a region including the road.

INDUSTRIAL APPLICABILITY

[0206] The techniques according to the present disclosure are applicable to a path planning system for agricultural machines, such as tractors, harvesters, rice transplanters, vehicles for crop management, vegetable transplanters, mowers, seeders, spreaders, or agricultural robots, for example.

REFERENCE SIGNS LIST

[0207] 10: storage device; 20: processing unit; 30: movable body; 31: global path; 32: local path; 33: LiDAR sensor; 34: camera; 35: GNSS unit; 40: obstacle; 50: GNSS satellite; 60: reference station; 70: field; 72: work area; 74: headland; 76: road; 80: network; 90: repository; 96: waiting area; 100: work vehicle; 101: vehicle body; 102: prime mover (engine); 103: transmission; 104: wheel; 105: cabin; 106: steering device; 107: driver's seat; 108: linkage device; 110: positioning device; 111: GNSS receiver; 112: RTK receiver; 115: inertial measurement unit (IMU); 116: processing circuit; 120: camera; 130: obstacle sensor; 140: LiDAR sensor; 150: sensors; 152: steering wheel sensor; 154: angle-of-turn sensor; 154; 156: axle sensor; 160: control system; 170: storage device; 170; 180: controller; 181-186: ECU; 190: communication device; 200: operational terminal; 210: operation switches; 220: buzzer; 240: drive device; 300: implement; 340: drive device; 380: controller; 390: communication device; 400: terminal device; 420: input device; 430: display device; 450: storage device; 460: processor; 470: ROM; 480: RAM; 490: communication device; 600: management computer; 660: processor; 670: storage device; 670: ROM; 680: RAM; 690: communication de-

vice; **1000**: map generation system

Claims

1. A map generation system to generate map data for an agricultural machine to automatically travel on a road around a field, the map generation system comprising:

a storage device to store a plurality of feature block images respectively associated with a plurality of types of features existing around the road; and
a processing unit,
wherein the processing unit:

acquires position distribution data on one or more types of features existing around the road, the position distribution data being generated based on at least one of sensor data from a LiDAR sensor and image data from an imager, the sensor data and the image data being output while a movable body including at least one of the LiDAR sensor and the imager is moving along the road, reads, from the storage device, one or more types of feature block images associated with the one or more types of features, and aligns the feature block images in accordance with the position distribution data to generate map data on a region including the road.

2. The map generation system of claim 1, wherein the processing unit:

displays, on a display screen, a graphical user interface (GUI) to set a width and a height of each of the plurality of feature block images, and aligns the one or more types of feature block images each having the width and the height set on the GUI to generate the map data.

3. The map generation system of claim 2, wherein the processing unit generates the map data by performing a process including, regarding each of the one or more types of features,

determining a length in a transverse direction, corresponding to a direction of the width, and a length in a longitudinal direction, corresponding to a direction of the height, of a region occupied by the feature, based on the position distribution data,
dividing the length in the transverse direction by the width of the feature block image corresponding to the feature to determine a transverse

number of the feature block images, dividing the length in the longitudinal direction by the height of the feature block image to determine a longitudinal number of the feature block images, aligning the feature block images by the transverse number in the transverse direction, and aligning the feature block images by the longitudinal number in the longitudinal direction.

4. The map generation system of any one of claims 1 to 3, wherein the processing unit:

recognizes the one or more types of features existing around the road based on at least one of the sensor data and the image data, and generates the position distribution data on the one or more types of features based on GNSS data output from a GNSS receiver included in the movable body and the sensor data.

5. The map generation system of claim 4, wherein the processing unit:

recognizes the one or more types of features including at least one of grass, tree, ditch, waterway, field and building existing around the road based on at least one of the sensor data and the image data, and aligns the one or more types of feature block images, associated with the recognized one or more types of features, in a region where the features exist on the map data, in accordance with the position distribution data, to generate the map data.

6. The map generation system of claim 4 or 5, wherein the processing unit recognizes the one or more types of features existing around the road by pattern matching or segmentation based on the image data.

7. The map generation system of any one of claims 4 to 6, wherein the processing unit:

detects a width of the road based on at least one of the sensor data and the image data, and generates the map data reflecting the width of the road.

8. The map generation system of any one of claims 4 to 7, wherein the processing unit:

detects a border between the road and the one or more types of features based on at least one of the sensor data and the image data, and aligns the one or more types of feature block images, associated with the one or more types of features, along, and outward of, the border

and disposes an image representing the road inward of the border to generate the map data.

9. The map generation system of any one of claims 4 to 8, wherein the processing unit generates the position distribution data representing a distribution of latitudes and longitudes of the one or more types of features based on the GNSS data and the sensor data.
5
10
10. The map generation system of any one of claims 1 to 9, wherein:
15
the storage device stores a plurality of pixel art images, respectively representing the plurality of types of features, as the plurality of feature block images, and
the processing unit aligns the pixel art images to generate the map data.
20
11. The map generation system of any one of claims 1 to 10, wherein:
25
the storage device stores a road block image associated with the road, as one of the plurality of feature block images, and
the processing unit aligns the one or more types of feature block images associated with the one or more types of features other than the road, and the road block image associated with the road, in accordance with the position distribution data to generate the map data.
30
12. The map generation system of any one of claims 1 to 11, wherein the processing unit generates a path for self-traveling of the agricultural machine along the road based on the map data.
35
13. The map generation system of any one of claims 1 to 12, further comprising:
40
a LiDAR sensor, and
the imager.
14. The map generation system of any one of claims 1 to 12, further comprising the movable body.
45
15. The map generation system of claim 14, wherein the movable body is the agricultural machine.
50
16. A map generation method for generating map data for an agricultural machine to automatically travel on a road around a field, the map generation method comprising:
55
acquiring position distribution data on one or more types of features existing around the road, the position distribution data being generated

based on at least one of sensor data from a LiDAR sensor and image data from an imager, the sensor data and the image data being output while a movable body including at least one of the LiDAR sensor and the imager is moving along the road;
reading, from a storage device, one or more types of feature block images associated with the one or more types of features; and
aligning the feature block images in accordance with the position distribution data to generate map data on a region including the road.

FIG. 1

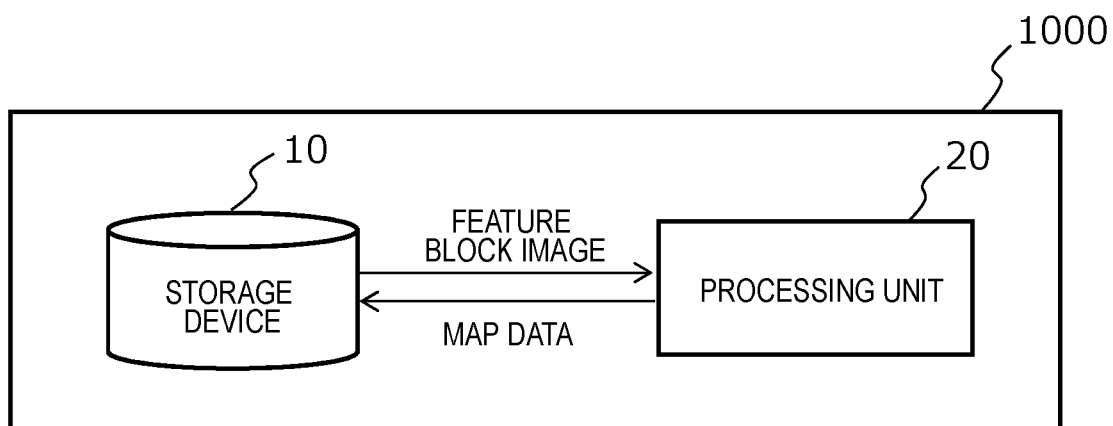


FIG. 2A

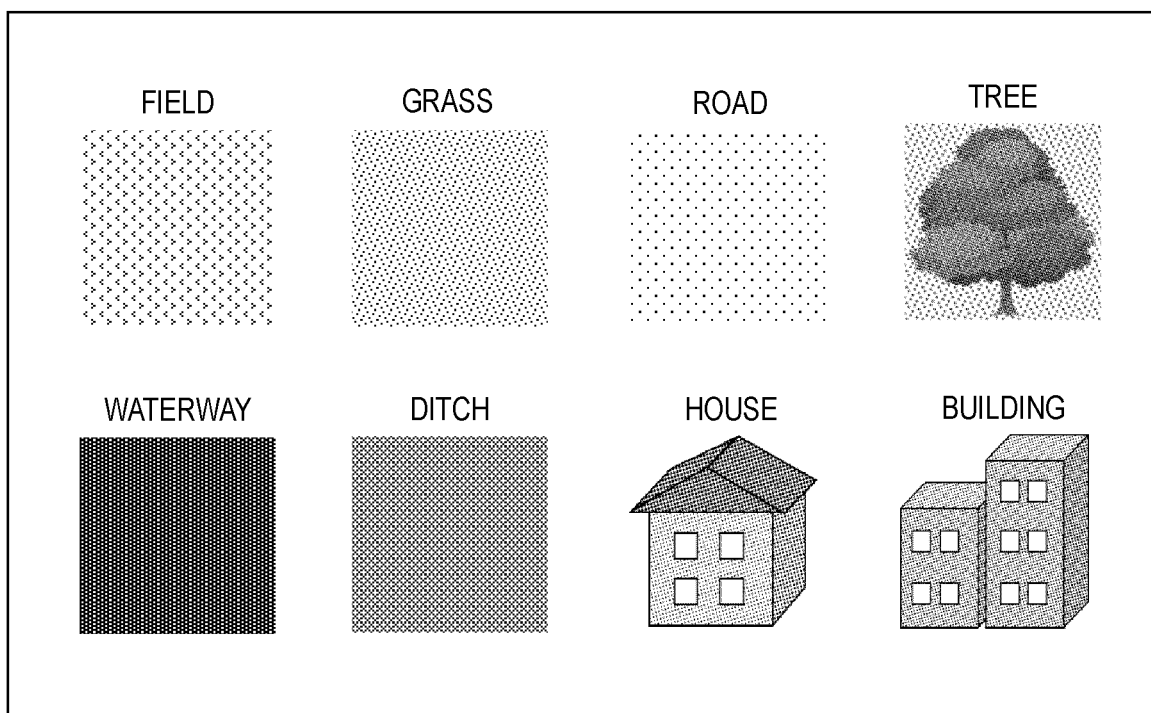


FIG. 2B

SETTING SCREEN

FIELD

W

H

W

m

H

m

GRASS

m

m

ROAD

m

m

△

▽

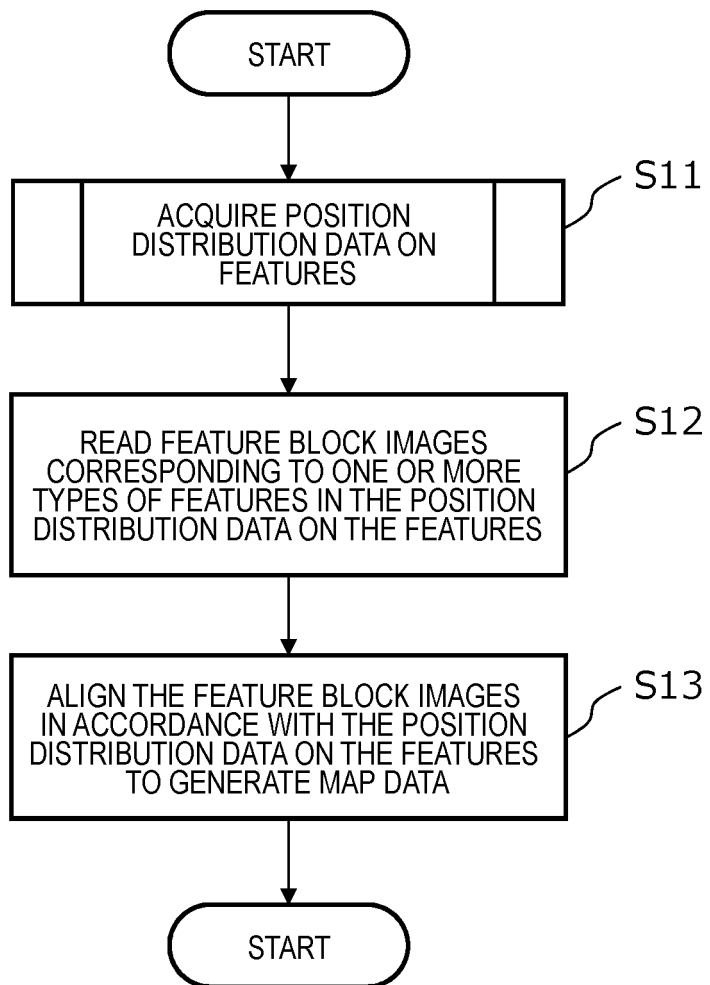
FIG. 3A

FIG. 3B

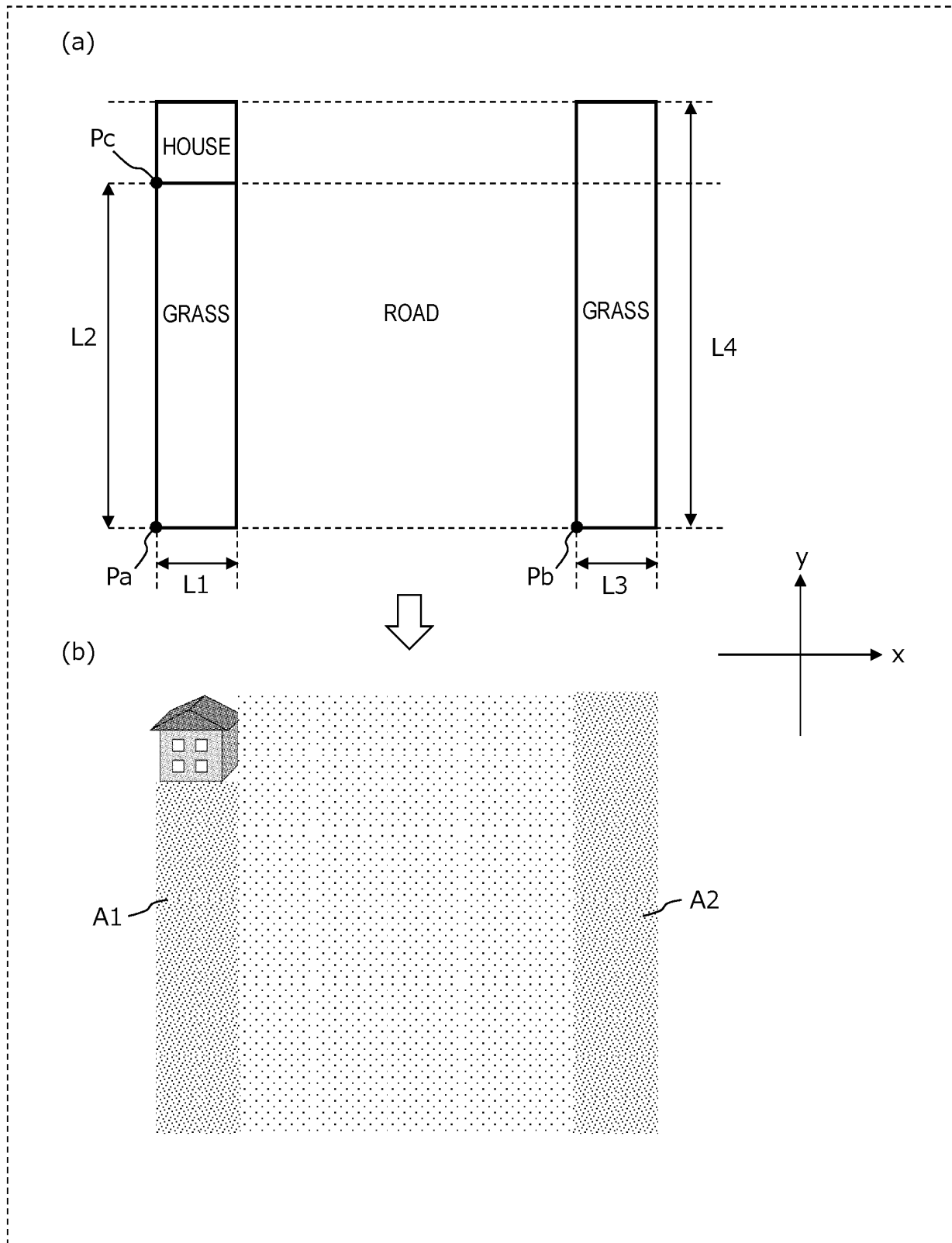


FIG. 4

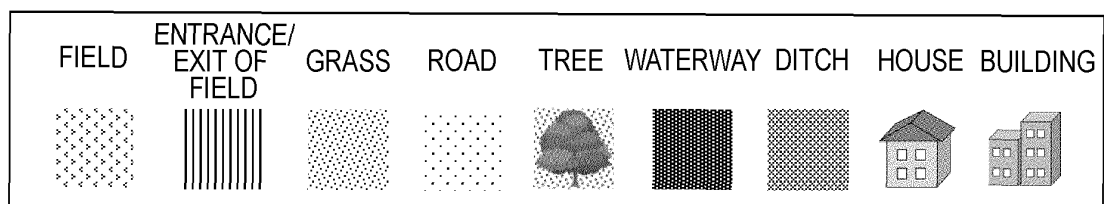
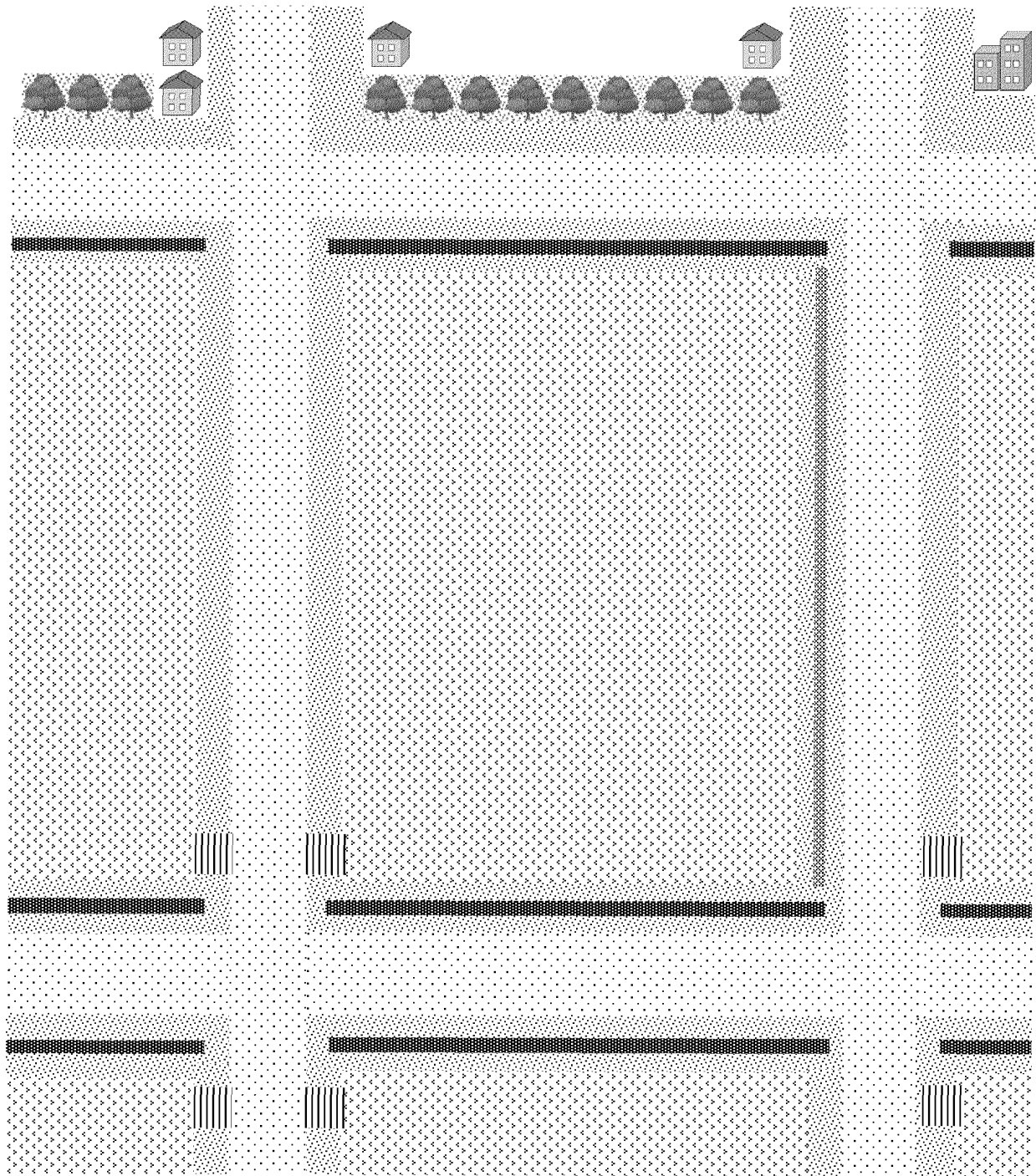


FIG. 5

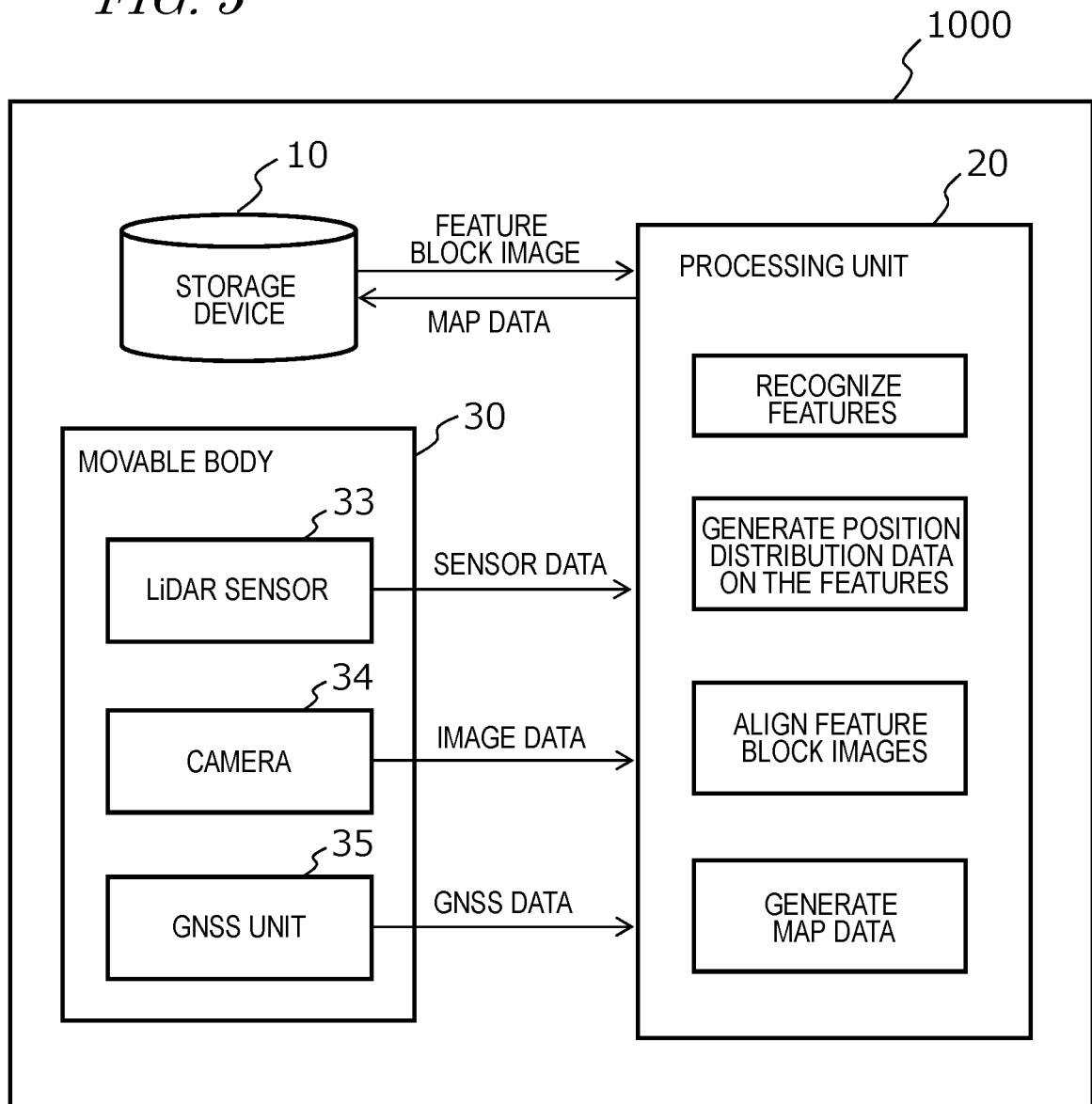


FIG. 6

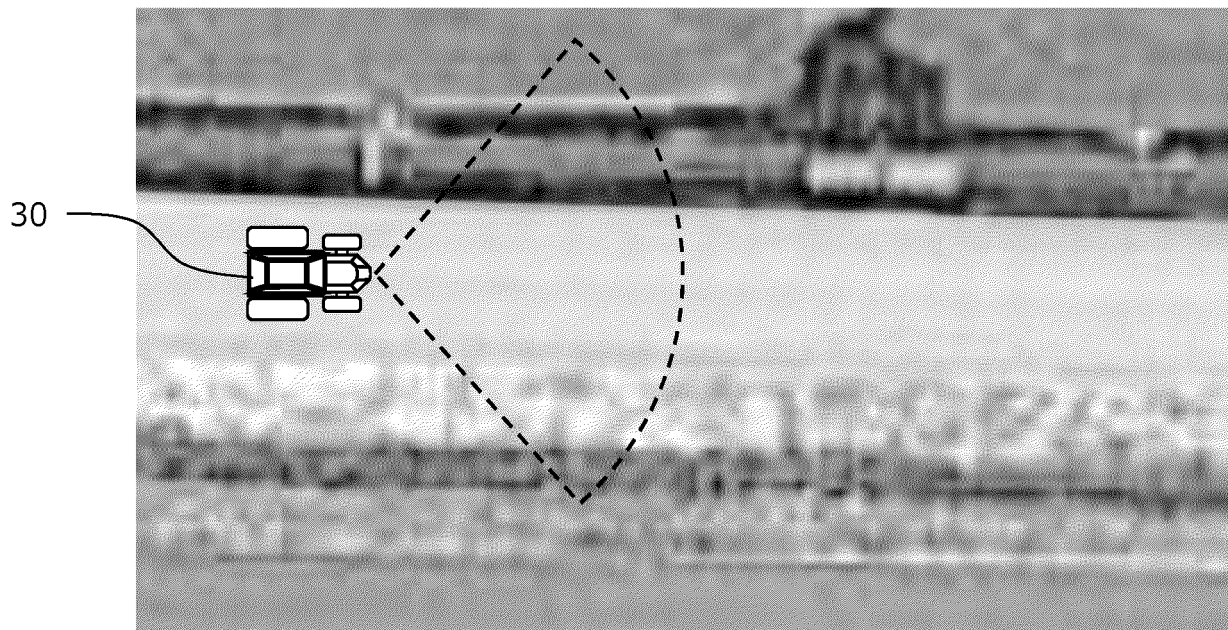


FIG. 7

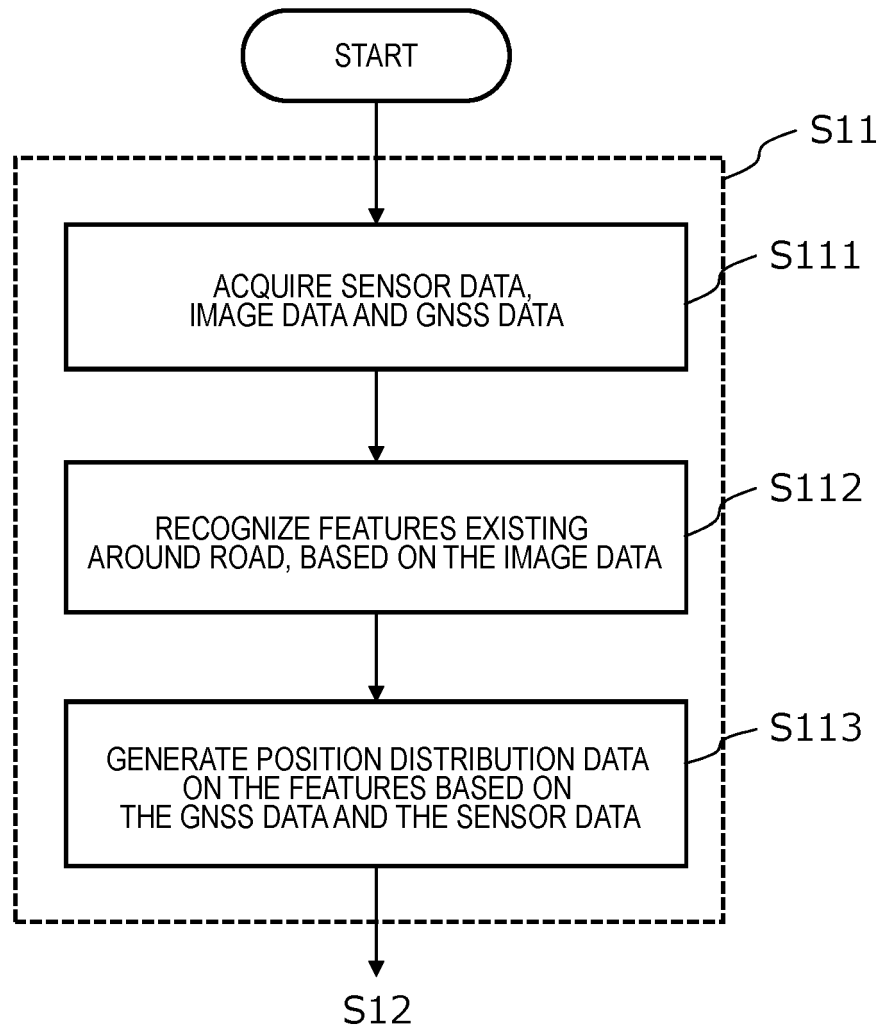


FIG. 8

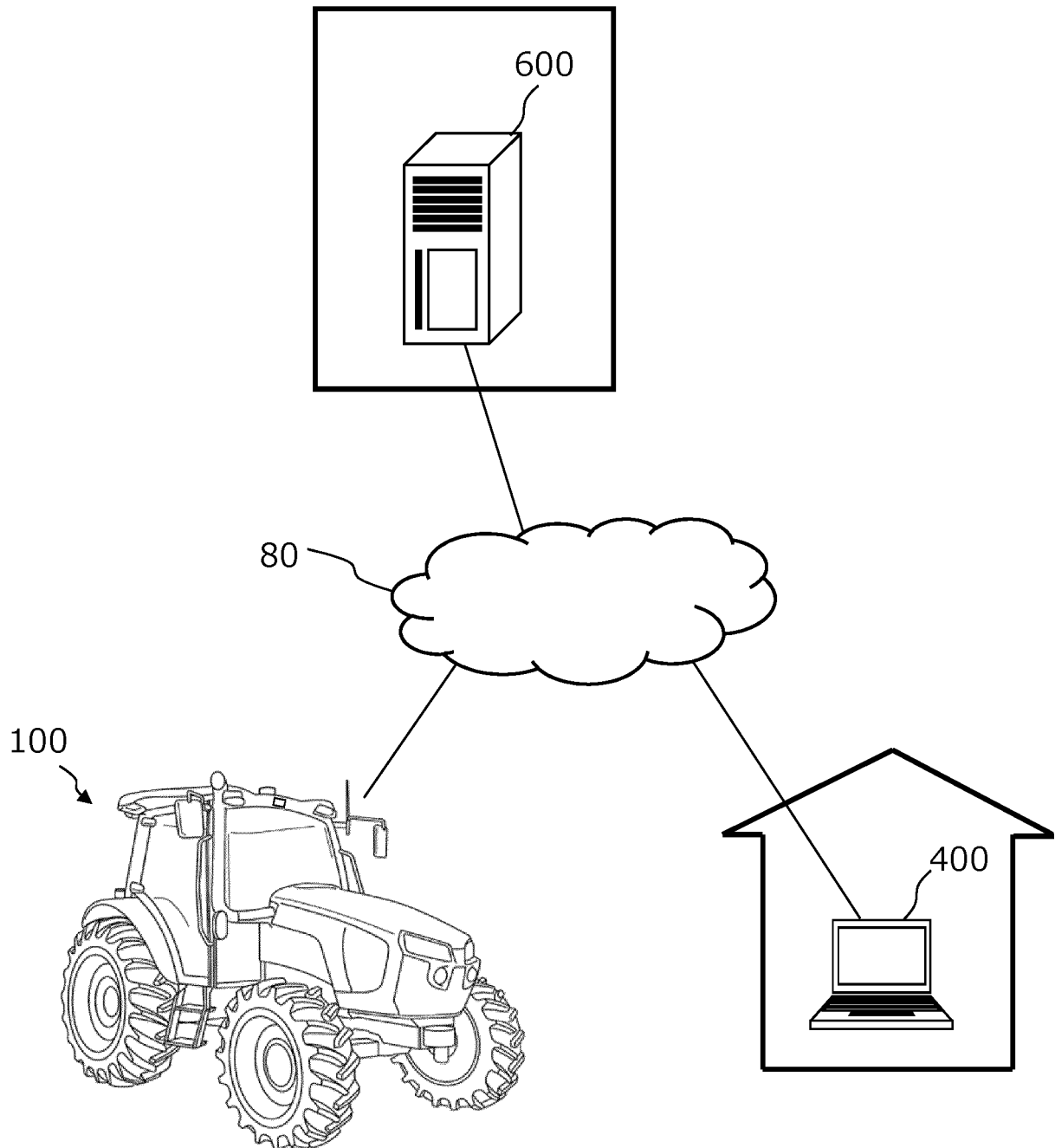


FIG. 9

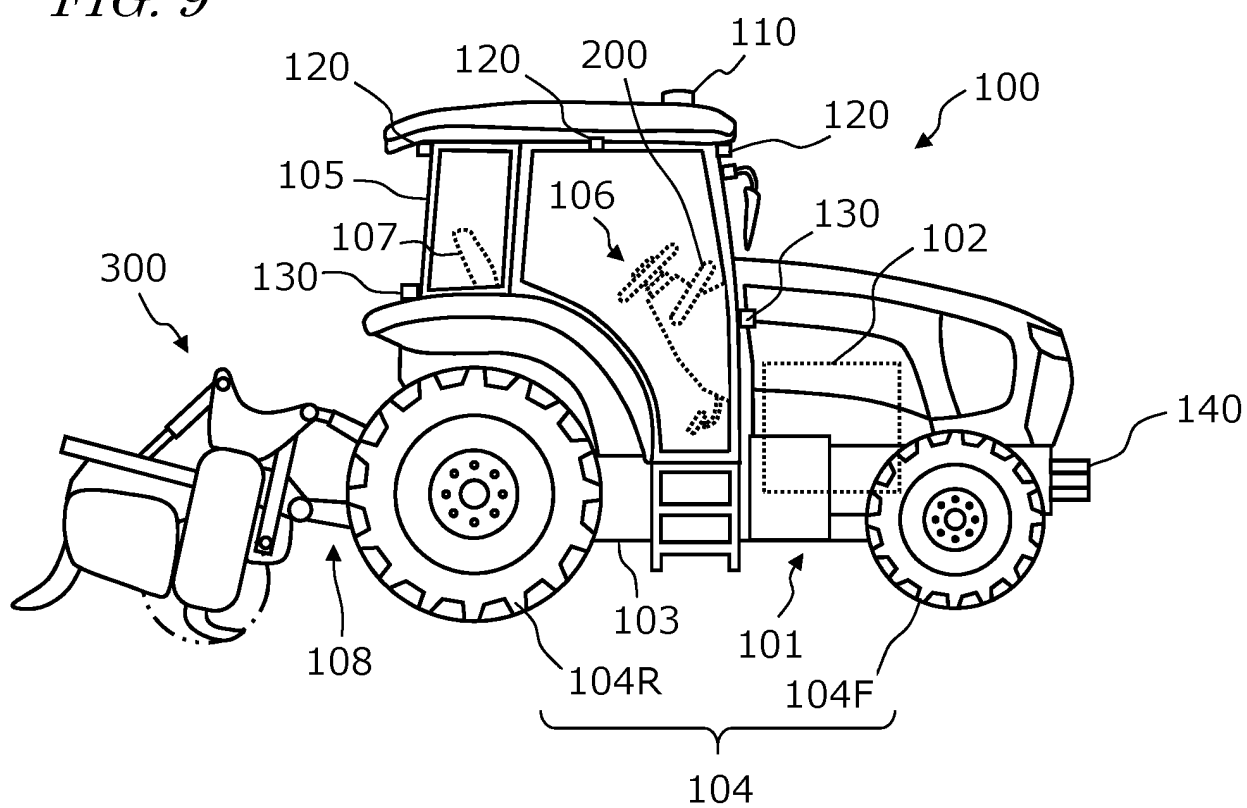


FIG. 10

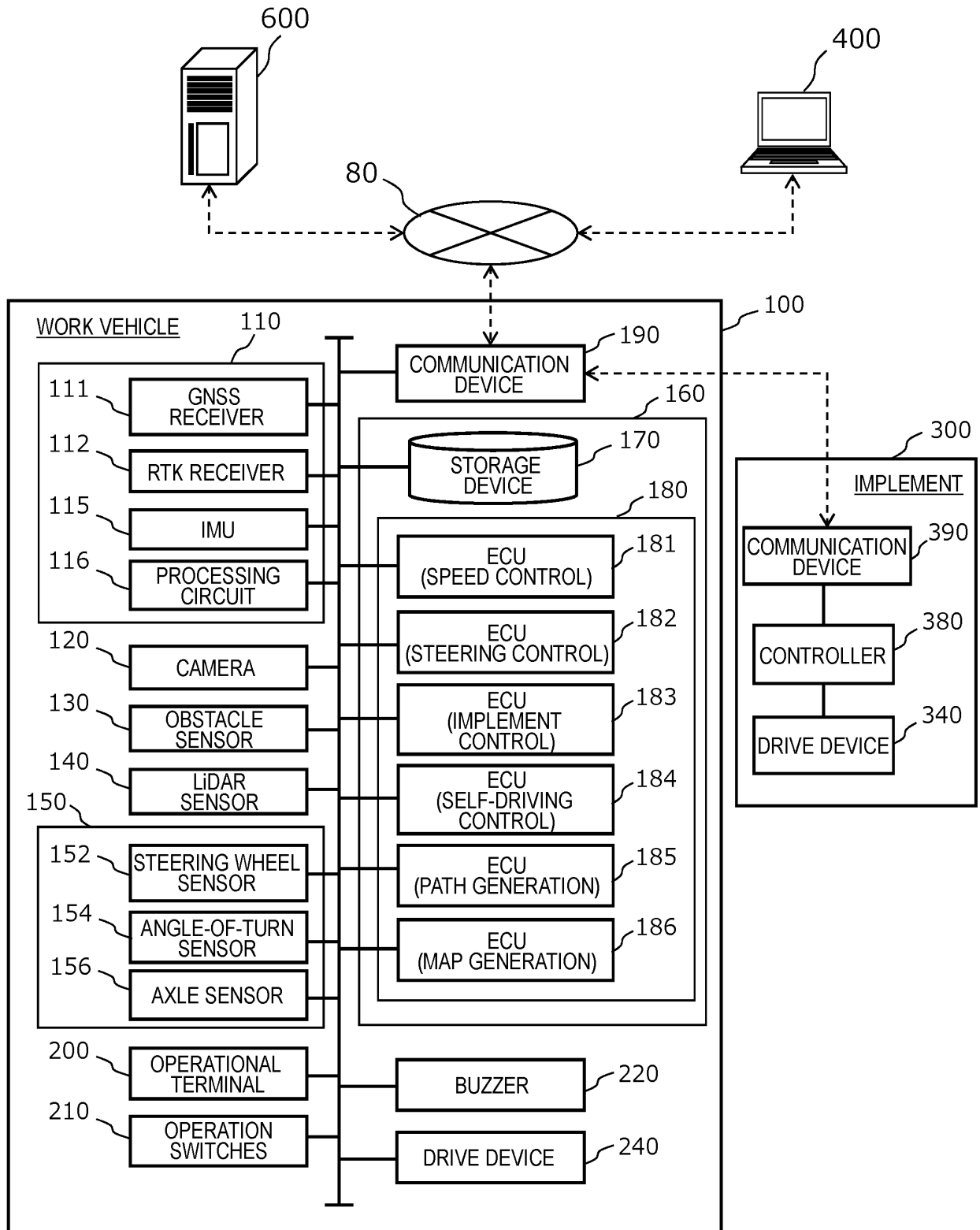


FIG. 11

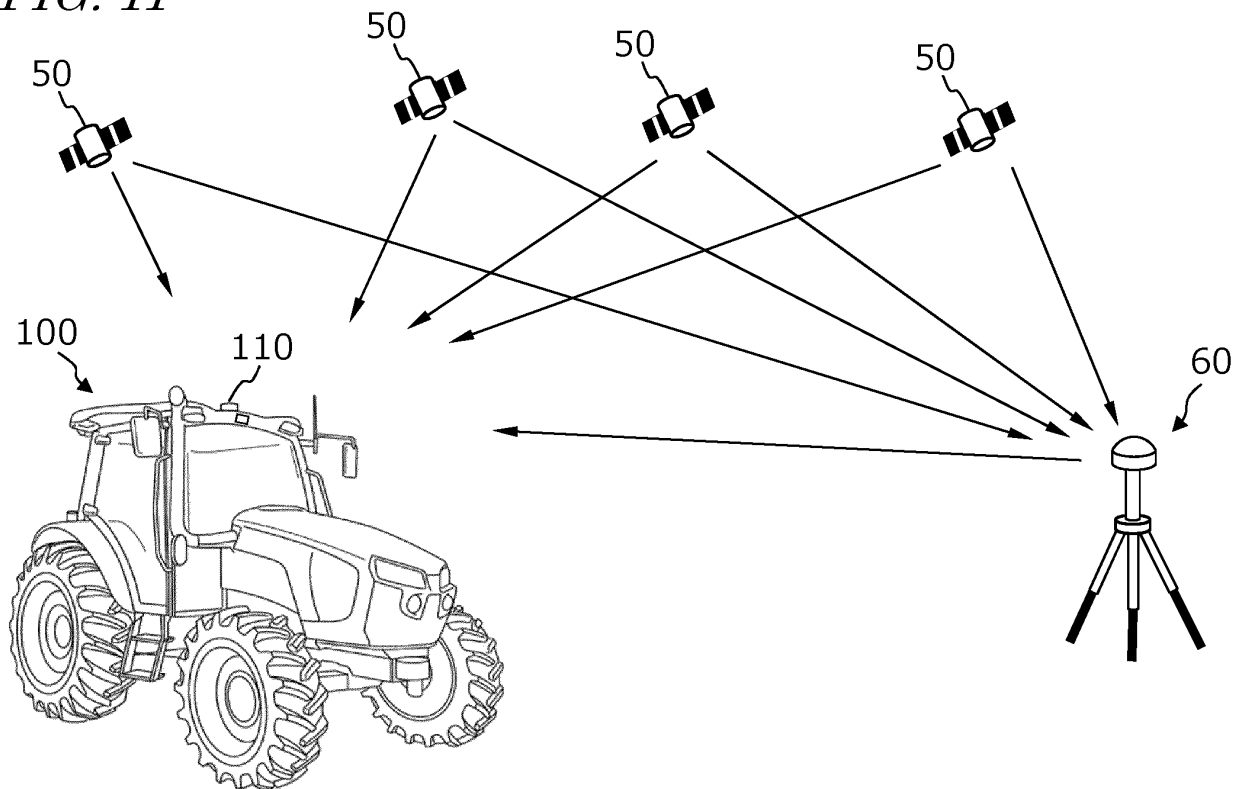


FIG. 12

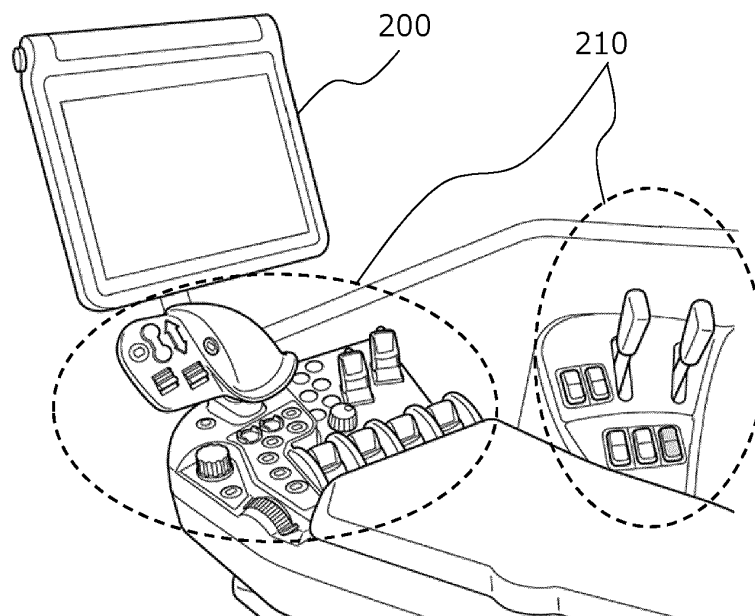


FIG. 13

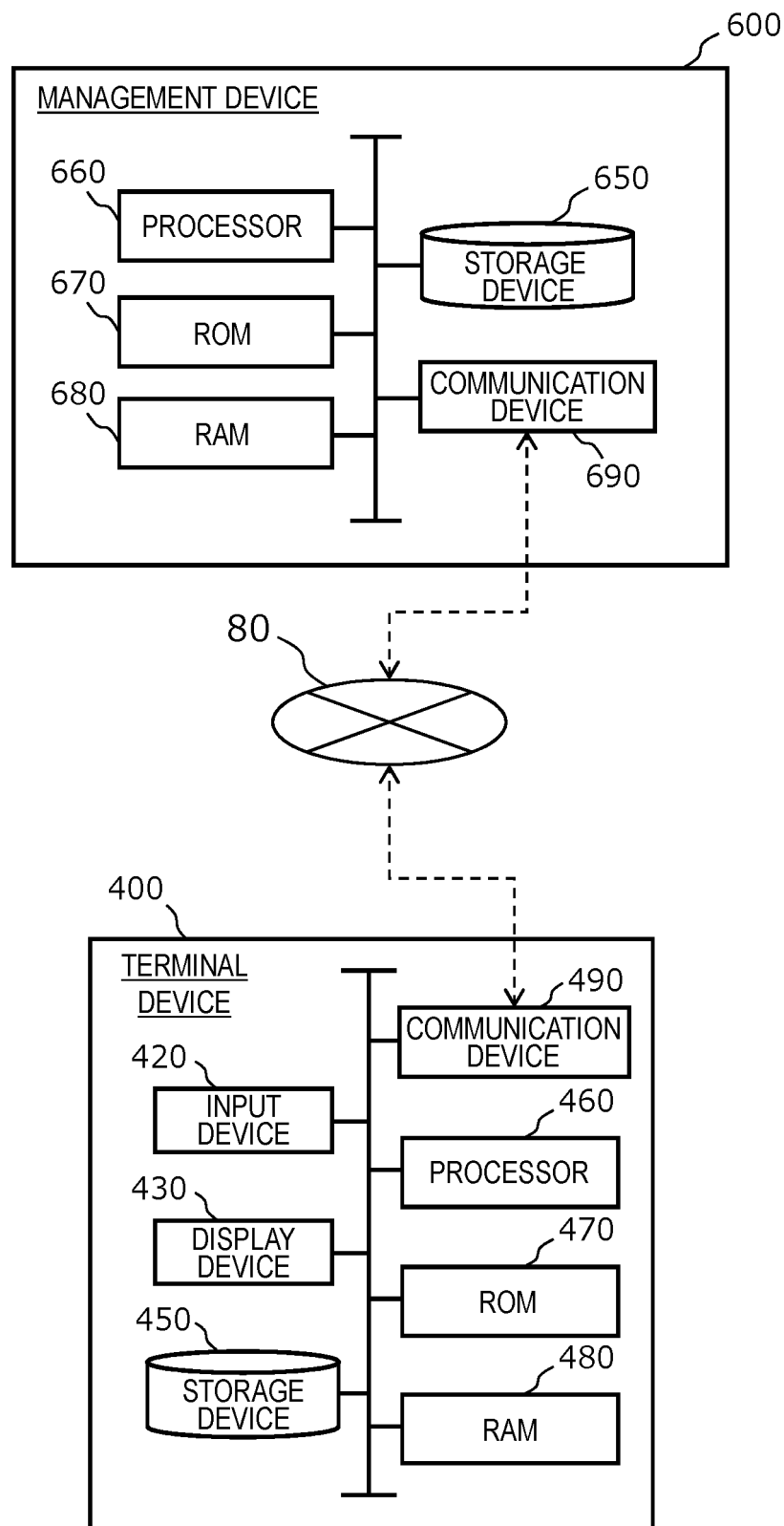


FIG. 14

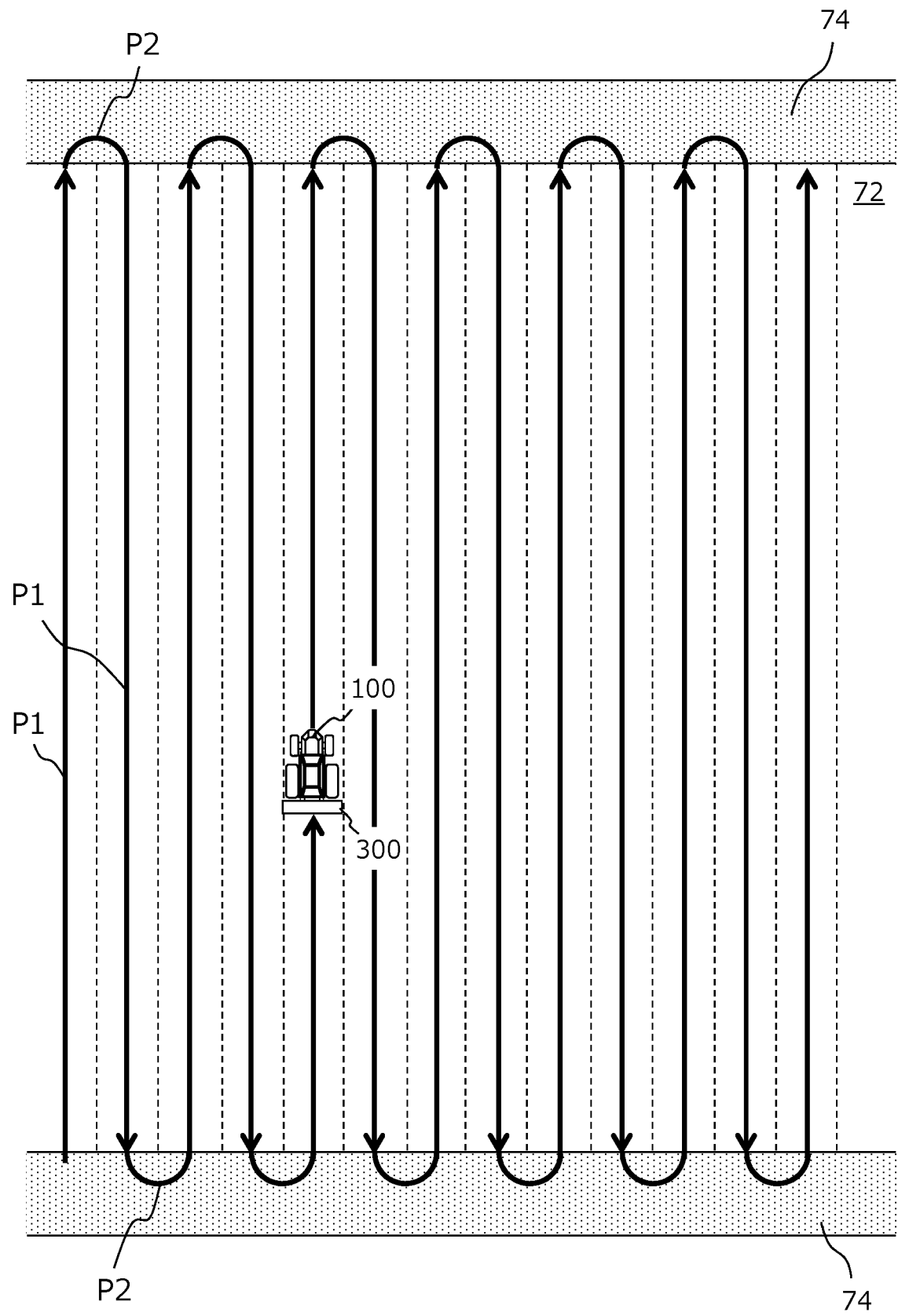


FIG. 15

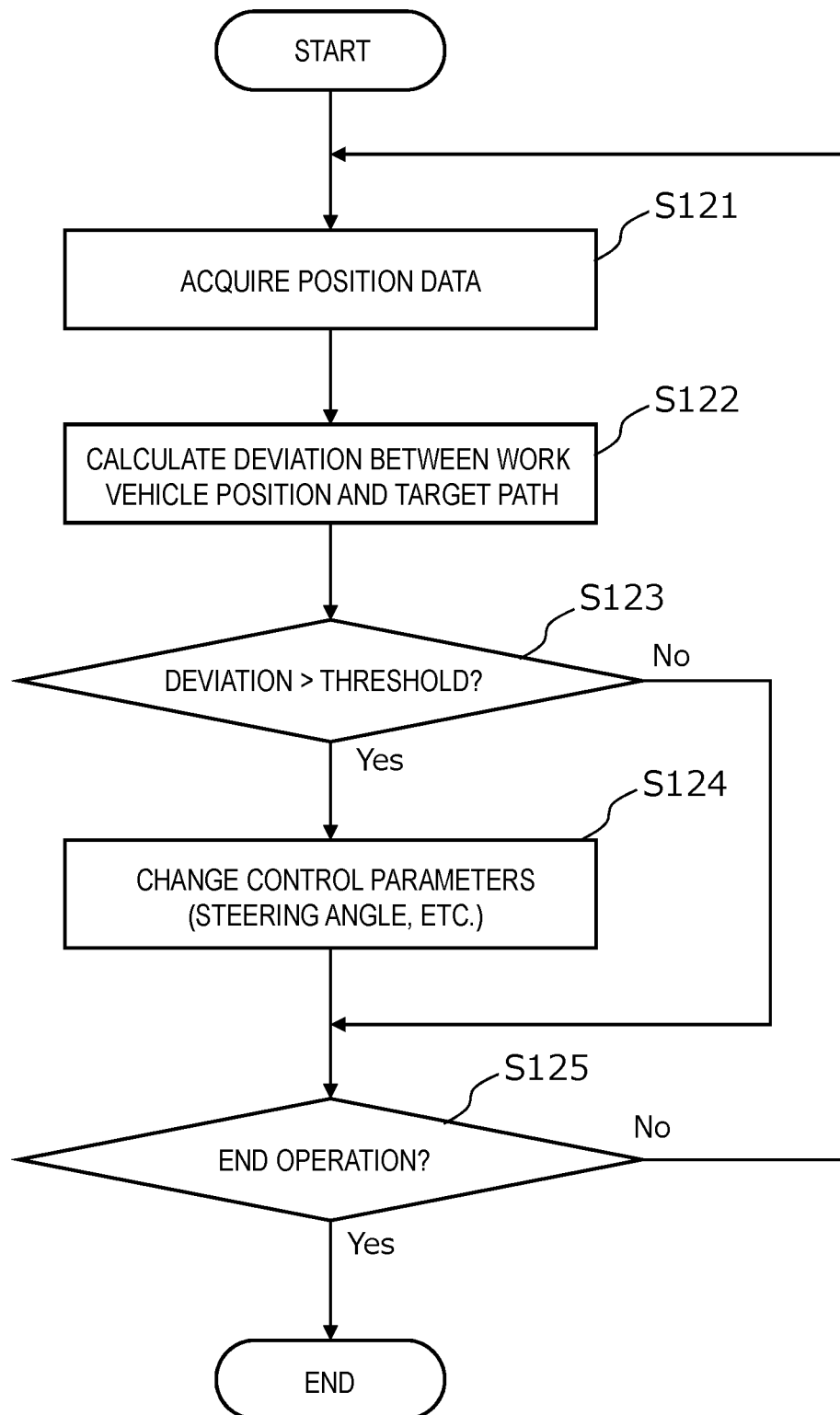


FIG. 16A

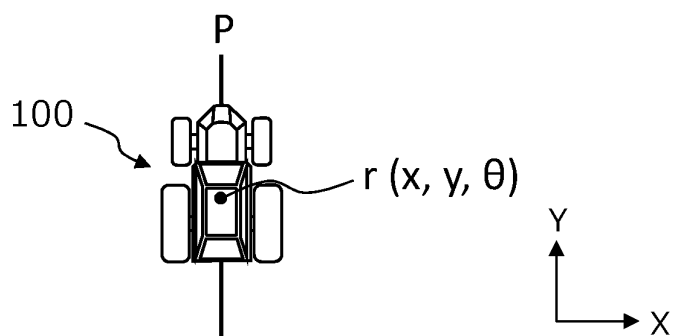


FIG. 16B

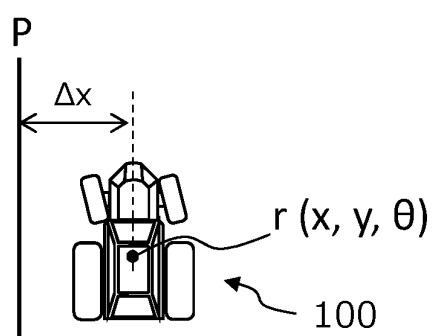


FIG. 16C

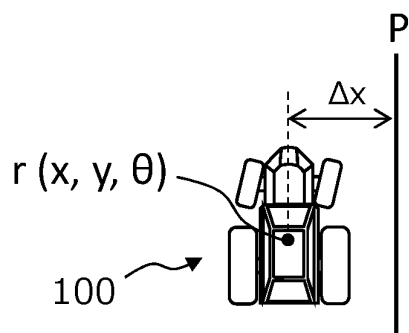


FIG. 16D

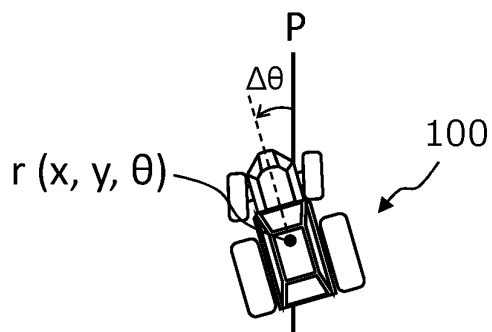


FIG. 17

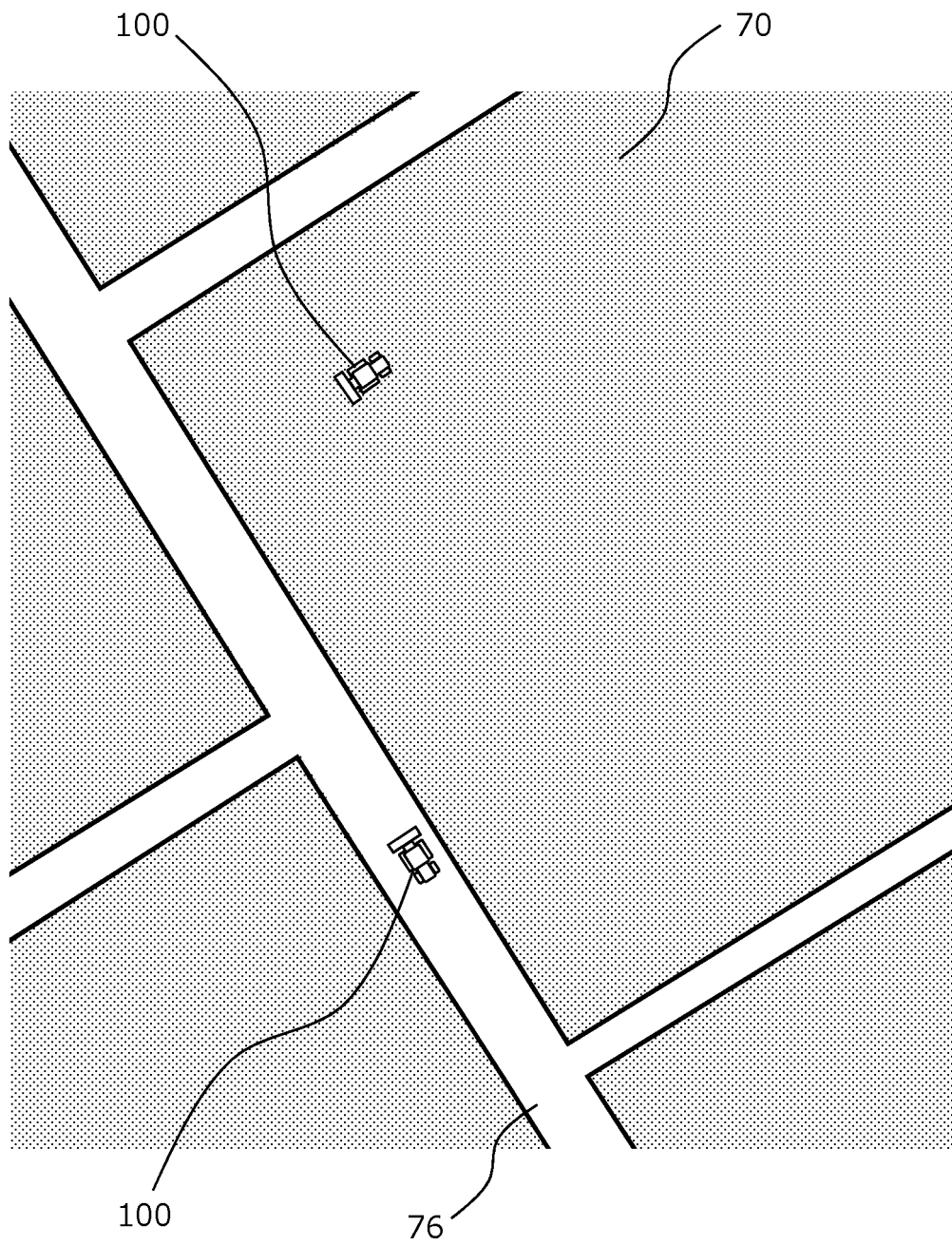


FIG. 18

AGRICULTURAL MACHINE	DATE/TIME	FIELD	TASK	IMPLEMENT
AGRICULTURAL MACHINE A	JUNE 21, 2021, 8:00 – 11:00	FIELD A	SPRAYING AGRICULTURAL CHEMICALS	IMPLEMENT A
AGRICULTURAL MACHINE A	JUNE 21, 2021, 12:00 – 14:00	FIELD B	SPRAYING AGRICULTURAL CHEMICALS	IMPLEMENT A
AGRICULTURAL MACHINE A	JUNE 21, 2021, 15:00 – 18:00	FIELD C	TILLING	IMPLEMENT B
AGRICULTURAL MACHINE A	JUNE 22, 2021, 8:00 – 12:00	FIELD D	TILLING	IMPLEMENT B
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.

FIG. 19

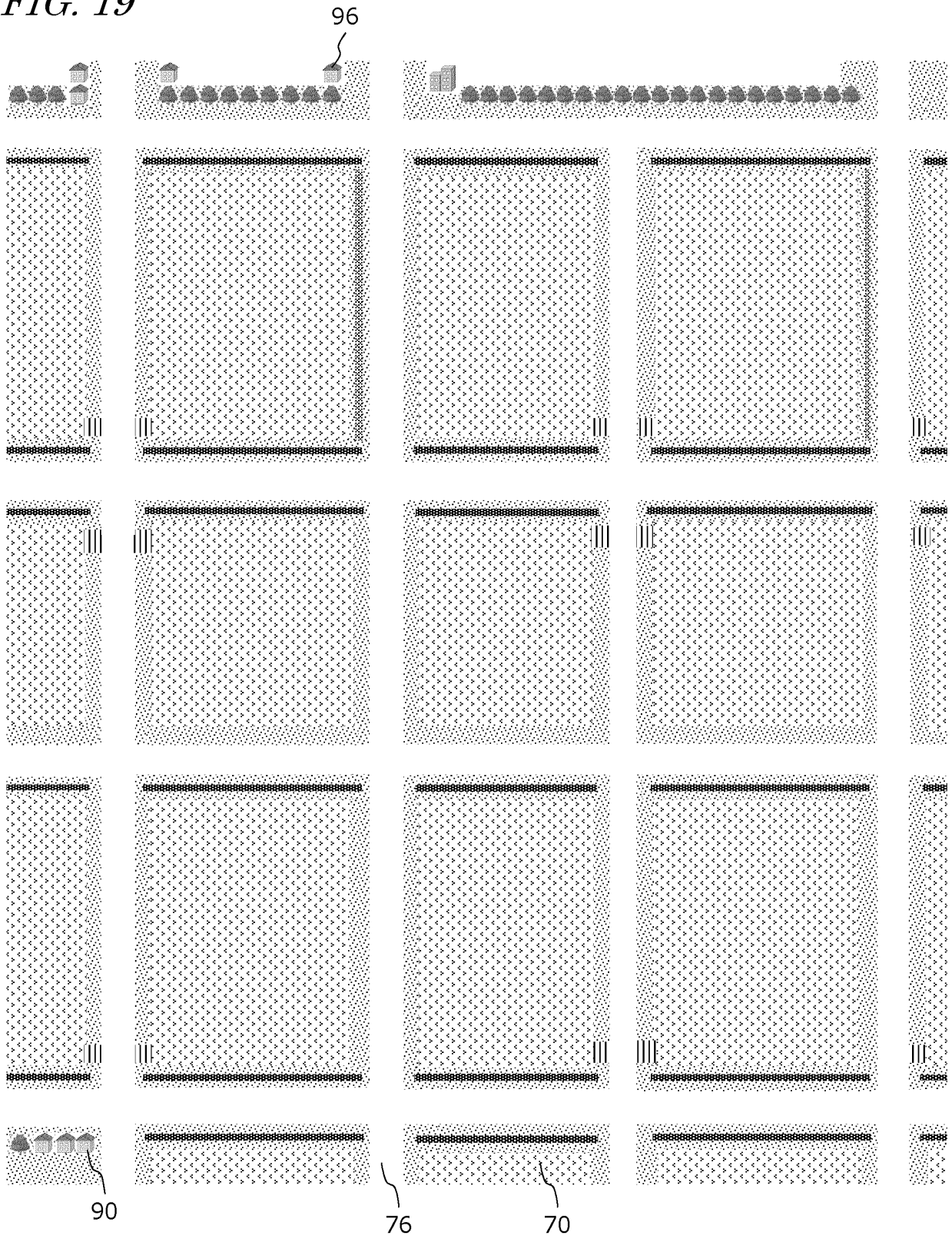


FIG. 20

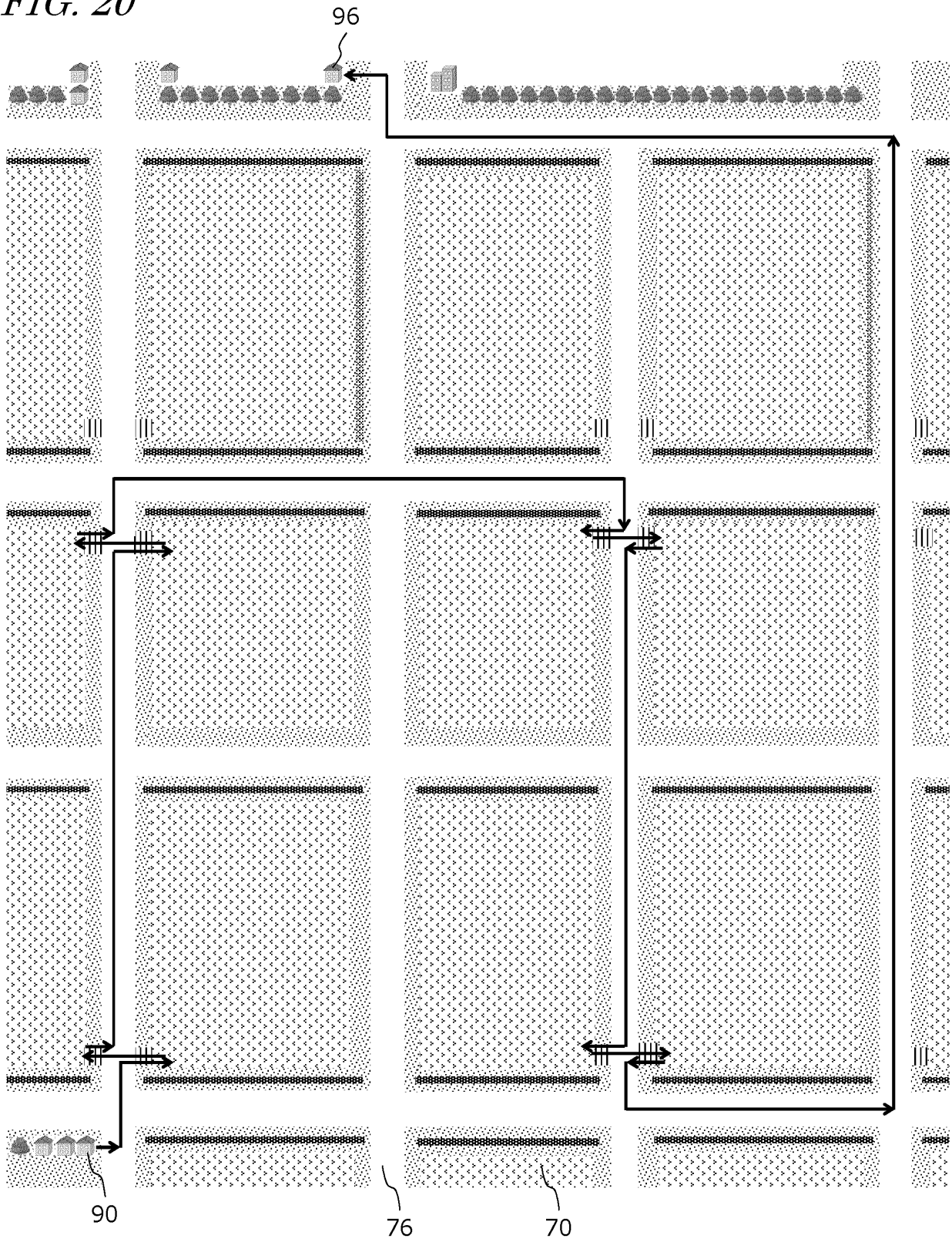
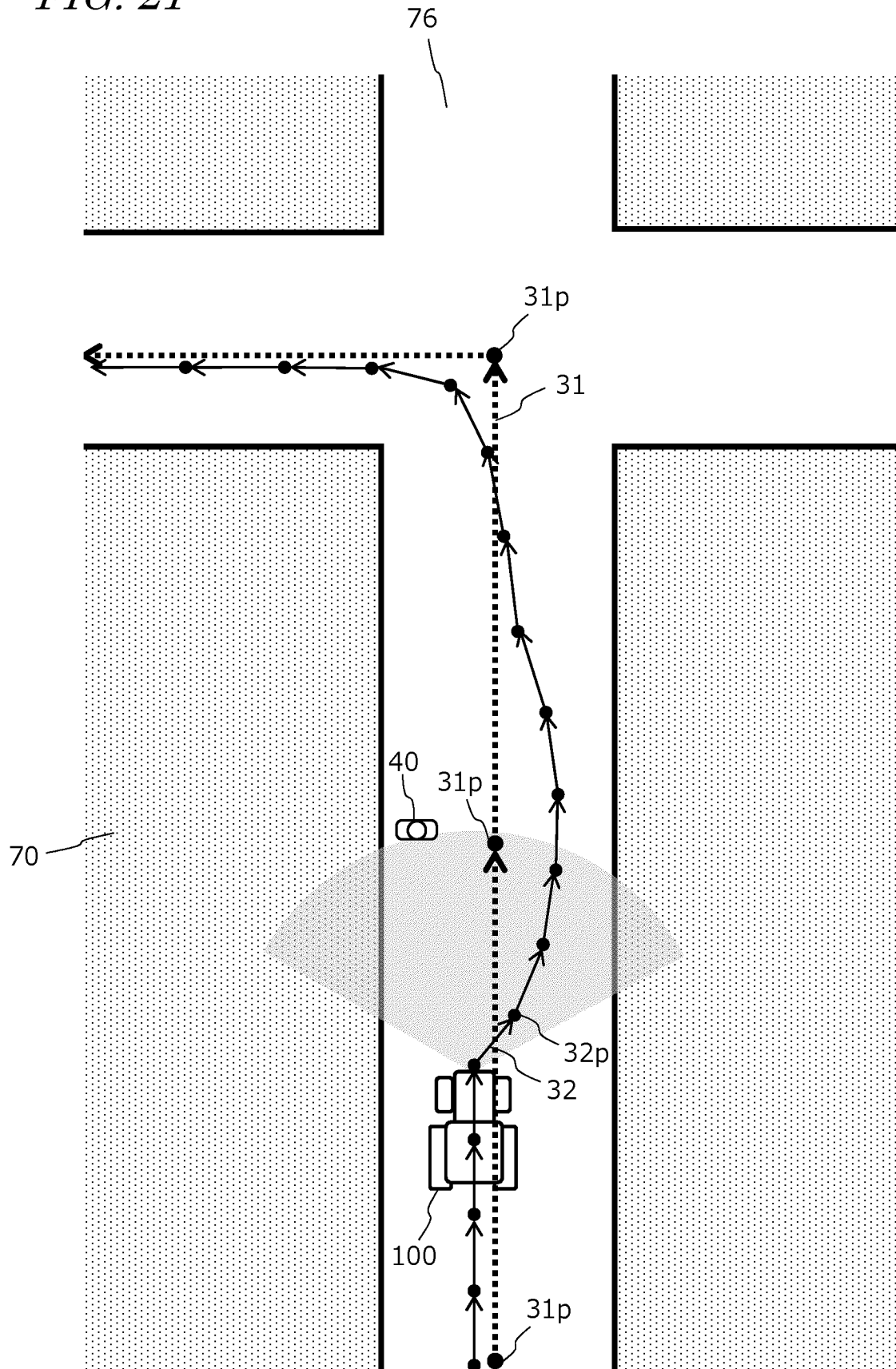


FIG. 21



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/040394

A. CLASSIFICATION OF SUBJECT MATTER

G09B 29/00(2006.01)i; **A01B 69/00**(2006.01)i; **G05D 1/02**(2020.01)i
 FI: G09B29/00 Z; A01B69/00 303M; G05D1/02 H; G05D1/02 N

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G09B29/00; G09B29/10; A01B69/00; G05D1/02; G01C21/26-21/36; G08G1/00-1/16; G06T11/60; A63F13/63

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2023
 Registered utility model specifications of Japan 1996-2023
 Published registered utility model applications of Japan 1994-2023

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2021/0018929 A1 (LG ELECTRONICS INC.) 21 January 2021 (2021-01-21) paragraphs [0082]-[0088], [0113]-[0136], [0208]-[0257], fig. 5, 9-12F	1, 10-16
A	paragraphs [0082]-[0088], [0113]-[0136], [0208]-[0257], fig. 5, 9-12F	2-9
Y	CN 110321184 A (BEIJING XINTANG SICHUANG EDUCATION TECHNOLOGY CO. LTD.) 11 October 2019 (2019-10-11) paragraphs [0036]-[0091]	1, 10-16
A	paragraphs [0036]-[0091]	2-9
A	US 2017/0223889 A1 (ROWBOT SYSTEMS LLC) 10 August 2017 (2017-08-10) paragraphs [0038]-[0046], fig. 1-5	1-16
A	JP 2017-161987 A (YANMAR CO., LTD.) 14 September 2017 (2017-09-14) paragraphs [0049]-[0061], fig. 7-11	1-16
A	US 2015/0012164 A1 (ELECTRONICS AND TELECOMMUNICATIONS RESEARCH INSTITUTE et al.) 08 January 2015 (2015-01-08) paragraphs [0041]-[0051], [0057]-[0061], fig. 1-3	1-16

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

05 January 2023

Date of mailing of the international search report

17 January 2023

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)
 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915
 Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/040394

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
US 2021/0018929 A1	21 January 2021	WO 2021/010757 A1 KR 10-2021-0009011 A	
CN 110321184 A	11 October 2019	(Family: none)	
US 2017/0223889 A1	10 August 2017	US 2019/0069475 A1	
JP 2017-161987 A	14 September 2017	WO 2017/154772 A1 KR 10-2018-0100355 A CN 108780318 A KR 10-2019-0119150 A CN 114859915 A	
US 2015/0012164 A1	08 January 2015	KR 10-2015-0005809 A	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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- JP 2021029218 A [0005]
- JP 2019154379 A [0005]